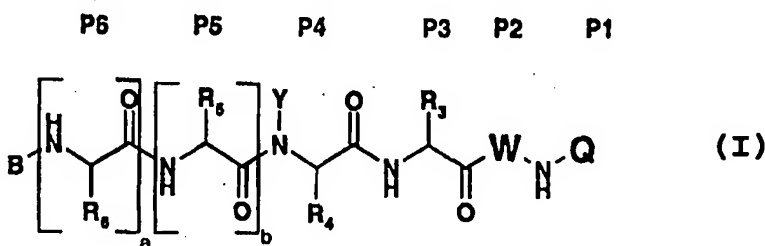




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(54) Title: HEPATITIS C INHIBITOR PEPTIDE ANALOGUES



(57) Abstract

Compound of formula (I) active against the Hepatitis C virus, wherein B is an acyl derivative; a is 0 or 1; R₆, when present, is carboxy(lower)alkyl; b is 0 or 1; R₅, when present, is C₁₋₆ alkyl, or carboxy(lower)alkyl; Y is H or C₁₋₆ alkyl; R₄ is C₁₋₁₀ alkyl; R₃ is C₁₋₁₀ alkyl; W is -NH-CH(R₂)-C(O)-, wherein R₂ is C₁₋₆ alkyl; C₆ or C₁₀ aryl; C₇₋₁₆ aralkyl; or carboxy(lower)alkyl; or W is a proline derivative; Q is a group of the formula -Z(R₁)-C(O)-R₁₃, wherein Z is CH or N; R₁ is C₁₋₆ alkyl or C₁₋₆ alkenyl both optionally substituted with thio or halo; and R₁₃ is an activated carbonyl substituent, or Q is a phosphonate group of the formula -CH(R₁)-P(O)R₁₅R₁₆ wherein R₁₅ and R₁₆ are independently C₆₋₂₀ aryloxy; and R₁ is as defined above.

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Hepatitis C Inhibitor Peptide Analogues

Field of the invention

5 The present invention relates to compounds, compositions and methods for the treatment of hepatitis C virus (HCV) infection. In particular, the present invention provides novel peptides and analogues thereof, pharmaceutical compositions
10 containing such peptides and methods for using these peptides in the treatment of HCV infection.

Background of the invention

15 Hepatitis C virus (HCV) is the major etiological agent of post-transfusion and community-acquired non-A non-B hepatitis worldwide. It is estimated that over 100 million people worldwide are infected by the virus. A high percentage of carriers become
20 chronically infected and many progress to chronic liver disease, so called chronic hepatitis C. This group is in turn at high risk for serious liver disease such as liver cirrhosis, hepatocellular carcinoma and terminal liver disease leading to
25 death.

The mechanism by which HCV establishes viral persistence and causes a high rate of chronic liver disease has not been thoroughly elucidated. It is
30 not known how HCV interacts with and evades the host immune system. In addition, the roles of cellular and humoral immune responses in protection against HCV infection and disease have yet to be established. Immunoglobulins have been reported for prophylaxis of

transfusion-associated viral hepatitis. However, the Center for Disease Control does not presently recommend immunoglobulins for this purpose.

5 The lack of an effective protective immune response is hampering the development of a vaccine or adequate post-exposure prophylaxis measures, so in the near-term, hopes are firmly pinned on antiviral interventions.

10

Various clinical studies have been conducted with the goal of identifying pharmaceutical agents capable of effectively treating HCV infection in patients afflicted with chronic hepatitis C. These studies have involved the use of interferon-alpha, alone and in combination with other antiviral agents. Such studies have shown that a substantial number of the participants do not respond to these therapies, and of those that do respond favorably, a large proportion were found to relapse after termination of treatment.

Until recently, interferon (IFN) was the only available therapy of proven benefit approved in the clinic for patients with chronic hepatitis C. However the sustained response rate is low, and interferon treatment also induces severe side-effects (i.e. retinopathy, thyroiditis, acute pancreatitis, depression) that diminish the quality of life of treated patients. Recently, interferon in combination with ribavirin has been approved for patients non-responsive to IFN alone. However, the side effects caused by IFN are not alleviated with this combination therapy.

Therefore, a need exists for the development of effective antiviral agents for treatment of HCV infection that overcomes the limitations of existing pharmaceutical therapies.

HCV is an enveloped positive strand RNA virus in the Flaviviridae family. The single strand HCV RNA genome is approximately 9500 nucleotides in length and has a single open reading frame (ORF) encoding a single large polyprotein of about 3000 amino acids. In infected cells, this polyprotein is cleaved at multiple sites by cellular and viral proteases to produce the structural and non-structural (NS) proteins. In the case of HCV, the generation of mature nonstructural proteins (NS2, NS3, NS4A, NS4B, NS5A, and NS5B) is effected by two viral proteases. The first one, as yet poorly characterized, cleaves at the NS2-NS3 junction; the second one is a serine protease contained within the N-terminal region of NS3 (henceforth referred to as NS3 protease) and mediates all the subsequent cleavages downstream of NS3, both in *cis*, at the NS3-NS4A cleavage site, and in *trans*, for the remaining NS4A-NS4B, NS4B-NS5A, NS5A-NS5B sites. The NS4A protein appears to serve multiple functions, acting as a cofactor for the NS3 protease and possibly assisting in the membrane localization of NS3 and other viral replicase components. The complex formation of the NS3 protein with NS4A seems necessary to the processing events, enhancing the proteolytic efficiency at all of the sites. The NS3 protein also exhibits nucleoside triphosphatase and RNA helicase activities. NS5B is

a RNA-dependent RNA polymerase that is involved in the replication of HCV.

A general strategy for the development of antiviral agents is to inactivate virally encoded enzymes that are essential for the replication of the virus. In this vein, patent application WO 97/06804 describes the (-) enantiomer of the nucleoside analogue cytosine-1,3-oxathiolane (also known as 3TC) as active against HCV. This compound, although reported as safe in previous clinical trials against HIV and HBV, has yet to be clinically proven active against HCV and its mechanism of action against the virus has yet to be reported.

15

Intense efforts to discover compounds which inhibit the NS3 protease or RNA helicase of HCV have led to the following disclosures:

- 20 • US patent 5,633,388 describes heterocyclic-substituted carboxamides and analogues as being active against HCV. These compounds are directed against the helicase activity of the NS3 protein of the virus but clinical tests have not yet been reported.
- 25 • A phenanthrenequinone has been reported by Chu et al (Tet. Lett., (1996), 7229-7232) to have activity against the HCV NS3 protease *in vitro*. No further development on this compound has been reported.
- 30 • A paper presented at the Ninth International Conference on Antiviral Research, Urabandai, Fukyshima, Japan (1996) (Antiviral Research, 30,

1, 1996; A23 (abstract 19)) reports thiazolidine derivatives to be inhibitory to the HCV protease.

Several studies have reported compounds inhibitory to other serine proteases, such as human leukocyte elastase. One family of these compounds is reported in WO 95/33764 (Hoechst Marion Roussel, 1995). The peptides disclosed in that application are morpholinylcarbonyl-benzoyl-peptide analogues that are structurally different from the peptides of the present invention.

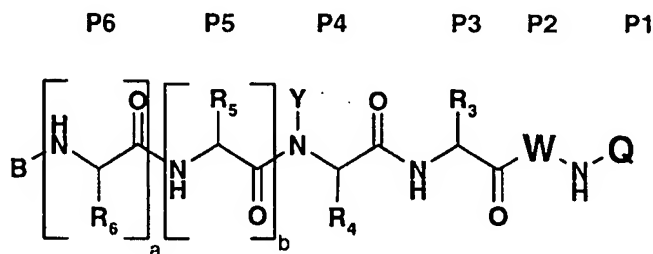
- WO 98/17679 from Vertex Pharmaceuticals Inc. discloses inhibitors of serine protease, particularly, Hepatitis C virus NS3 protease. These inhibitors are peptide analogues based on the NS5A/5B natural substrate that contain C-terminal aldehydes, α -ketoamides and fluorinated ketones.
- Hoffman LaRoche has also reported hexapeptides that are proteinase inhibitors useful as antiviral agents for the treatment of HCV infection. These peptides contain an aldehyde or a boronic acid at the C-terminus.
- Steinkühler et al. and Ingallinella et al. have published on NS4A-4B product inhibition (Biochemistry (1998), 37, 8899-8905 and 8906-8914). However, these peptides and analogues were published after the priority date of the present application.

One advantage of the present invention is that it provides peptides that are inhibitory to the NS3 protease of the hepatitis C virus.

Summary of the invention

We investigated peptides potentially inhibitory to the NS3 protease. The discovery that the N-terminal cleavage product (Ac-D-D-I-V-P-C-OH) of an analogue of a natural substrate of the NS3 protease was inhibitory led us to the peptide analogues of the invention.

Included in the scope of the invention are compounds of formula (I):



(I)

wherein **B** is an acyl derivative of formula $\text{R}_{11}-\text{C}(\text{O})-$ wherein R_{11} is C_{1-10} alkyl C_{3-10} cycloalkyl optionally substituted with carboxyl; or R_{11} is C_6 or C_{10} aryl or C_{7-16} aralkyl optionally substituted with a C_{1-6} alkyl; **a** is 0 or 1;

R_6 , when present, is carboxy(lower)alkyl;

b is 0 or 1;

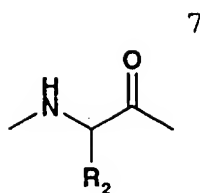
R_5 , when present, is C_{1-6} alkyl, or carboxy(lower)alkyl;

Y is H or C_{1-6} alkyl;

R_4 is C_{1-10} alkyl; cycloalkyl C_{3-10} ;

R_3 is C_{1-10} alkyl; cycloalkyl C_{3-10} ;

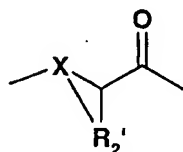
W is a group of formula II:



Formula II

wherein R_2 is C_{1-10} alkyl or C_{3-7} cycloalkyl optionally substituted with carboxyl; C_6 or C_{10} aryl; or C_{7-16} aralkyl; or

W is a group of formula II':



Formula II'

10

wherein X is CH or N; and

R_2' is C_{3-4} alkylene that joins X to form a 5- or 6-membered ring, said ring optionally substituted with OH; SH; NH_2 ; carboxyl; R_{12} ; OR_{12} , SR_{12} , NHR_{12} or $NR_{12}R_{12}'$

15 wherein R_{12} and R_{12}' are independently:

cyclic C_{3-16} alkyl or acyclic C_{1-16} alkyl or cyclic C_{3-16} alkenyl or acyclic C_{2-16} alkenyl, said alkyl or alkenyl optionally substituted with NH_2 , OH, SH, halo, or carboxyl; said alkyl or alkenyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N; or

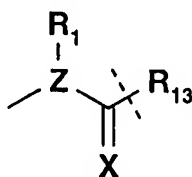
20

R_{12} and R_{12}' are independently C_6 or C_{10} aryl or C_{7-16} aralkyl optionally substituted with C_{1-6}

25

alkyl, NH_2 , OH, SH, halo, carboxyl or carboxy(lower)alkyl; said aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;

said cyclic alkyl, cyclic alkenyl, aryl or
 aralkyl being optionally fused with a second 5-
 , 6- or 7-membered ring to form a cyclic system
 or heterocycle, said second ring being
 5 optionally substituted with NH_2 , OH, SH, halo,
 carboxyl or carboxy(lower)alkyl; said second
 ring optionally containing at least one
 heteroatom selected independently from the group
 consisting of: O, S, and N;
 10 Q is a group of the formula:



wherein Z is CH or N;
 X is O or S;
 R₁ is H, C₁₋₆ alkyl or C₁₋₆ alkenyl both optionally
 15 substituted with thio or halo;
 and
 when Z is CH, then R₁₃ is H; CF₃; CF₂CF₃; CH₂-R₁₄;
 CH(F)-R₁₄; CF₂-R₁₄; NR₁₄R₁₄' S-R₁₄; or CO-NH-R₁₄ wherein
 R₁₄ and R₁₄' are independently hydrogen, cyclic
 20 C₃₋₁₀ alkyl or acyclic C₁₋₁₀ alkyl or cyclic C₃₋₁₀
 alkenyl or acyclic C₂₋₁₀ alkenyl, said alkyl or
 alkenyl optionally substituted with NH₂, OH, SH,
 halo or carboxyl; said alkyl or alkenyl
 optionally containing at least one heteroatom
 25 selected independently from the group consisting
 of: O, S, and N; or
 R₁₄ and R₁₄' are independently C₆ or C₁₀ aryl or
 C₇₋₁₆ aralkyl optionally substituted with C₁₋₆
 alkyl, NH₂, OH, SH, halo, carboxyl or
 30 carboxy(lower)alkyl or substituted with a
 further C₃₋₇ cycloalkyl, C₆ or C₁₀ aryl, or

heterocycle; said aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;

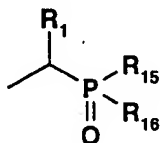
5 said cyclic alkyl, cyclic alkenyl, aryl or aralkyl being optionally fused with a second 5-, 6-, or 7-membered ring to form a cyclic system or heterocycle, said second ring being optionally substituted with NH_2 , OH, SH, halo, 10 carboxyl or carboxy(lower)alkyl or substituted with a further C_{3-7} cycloalkyl, C_6 or C_{10} aryl, or heterocycle; said second ring optionally containing at least one heteroatom selected independently from the group consisting of: O, 15 S, and N;

or R_{14} and R_{14}' are independently C_{1-4} alkyl which when joined together with N form a 3 to 6-membered nitrogen-containing ring which is optionally fused with a further C_{3-7} cycloalkyl, 20 C_6 or C_{10} aryl or heterocycle;

with the proviso that when Z is CH, then R_{13} is not an α -amino acid or an ester thereof;

when Z is N, then R_{13} is H; carboxy; C_{1-6} alkyl 25 optionally substituted with carboxy; $\text{CH}_2\text{-R}_{14}$; $\text{CHR}_{14}\text{R}_{14}'$; CH(F)-R_{14} ; O-R_{14} ; $\text{NR}_{14}\text{R}_{14}'$ or S-R_{14} wherein R_{14} and R_{14}' are as defined above; or

Q is a phosphonate group of the formula:



wherein R_{15} and R_{16} are independently C_{6-20} aryloxy; and R_1 is as defined above.

5 Included within the scope of this invention is a pharmaceutical composition comprising an anti-hepatitis C virally effective amount of a compound of formula I, or a therapeutically acceptable salt or ester thereof, in admixture with a pharmaceutically acceptable carrier medium or auxiliary agent.

10

An important aspect of the invention involves a method of treating a hepatitis C viral infection in a mammal by administering to the mammal an anti-hepatitis C virally effective amount of the compound
15 of formula I, or a therapeutically acceptable salt or ester thereof or a composition as described above.

Another important aspect involves a method of inhibiting the replication of hepatitis C virus by
20 exposing the virus to a hepatitis C viral NS3 protease inhibiting amount of the compound of formula I, or a therapeutically acceptable salt or ester thereof or a composition as described above.

25 Still another aspect involves a method of treating a hepatitis C viral infection in a mammal by administering thereto an anti-hepatitis C virally effective amount of a combination of the compound of formula I, or a therapeutically acceptable salt or
30 ester thereof, and an interferon. A pharmaceutical composition comprising the combination in admixture with a pharmaceutically acceptable carrier medium or auxiliary agent is also within the scope of this invention.

35

Detailed description of the invention

As used herein, the following definitions apply unless otherwise noted:

5

With reference to the instances where (R) or (S) is used to designate the configuration of a radical, e.g. R₄ of the compound of formula I, the designation is done in the context of the compound and not in the context of the radical alone.

10

The natural amino acids, with exception of glycine, contain a chiral carbon atom. Unless otherwise specifically indicated, the compounds containing natural amino acids with the L-configuration are preferred. However, applicants contemplate that when specified, some amino acids of the formula I can be of either D- or L- configuration or can be mixtures of D- and L-isomers, including racemic mixtures.

20

The designation "P1, P2, P3 et." as used herein refer to the position of the amino acid residues starting from the C-terminus end of the peptide analogues and extending towards the N-terminus (i.e. P1 refers to position 1 from the C-terminus, P2: second position from the C-terminus, etc.) (see Berger A. & Schechter I., Transactions of the Royal Society London series, (1970), B257, 249-264).

25

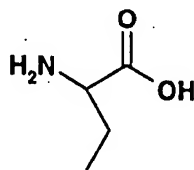
The abbreviations for the α -amino acids are set forth in Table A.

30

Table A

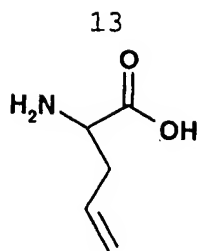
AMINO ACID	SYMBOL
Allylglycine	AlGly
Aminobutyric acid	Abu
Alanine	Ala
Aspartic acid	Asp
Cysteine	Cys
Cyclohexylalanine	Cha
Cyclohexylglycine (also named: 2-amino-2-cyclohexylacetic acid)	Chg
Glutamic acid	Glu
Isoleucine	Ile
Leucine	Leu
Norvaline	Nva
Phenylalanine	Phe
Pipecolic acid	Pip
Proline	Pro
4 (R)-Hydroxyproline	Hyp
4 (R)-Benzyloxyproline	Hyp(4-Bn)
Valine	Val
tert-Butylglycine	Tbg

As used herein the term "aminobutyric acid" refers to a compound of formula:

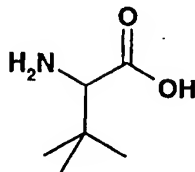


5.

As used herein the term "allylglycine" refers to a compound of formula:



As used herein the term "tert-butylglycine" refers to a compound of formula:



5

The term "residue" with reference to an amino acid or amino acid derivative means a radical derived from the corresponding α -amino acid by eliminating the hydroxyl of the carboxy group and one hydrogen of the α -amino group. For instance, the terms Gln, Ala, Gly, Ile, Arg, Asp, Phe, Ser, Leu, Cys, Asn, Sar and Tyr represent the "residues" of L-glutamine, L-alanine, glycine, L-isoleucine, L-arginine, L-aspartic acid, L-phenylalanine, L-serine, L-leucine, L-cysteine, L-asparagine, sarcosine and L-tyrosine, respectively.

The term "side chain" with reference to an amino acid or amino acid residue means a group attached to the α -carbon atom of the α -amino acid. For example, the R-group side chain for glycine is hydrogen, for alanine it is methyl, for valine it is isopropyl. For the specific R-groups or side chains of the α -amino acids reference is made to A.L. Lehninger's text on Biochemistry (see chapter 4).

The term "halo" as used herein means a halogen radical selected from bromo, chloro, fluoro or iodo.

5 The term "C₁₋₆ alkyl" or "(lower)alkyl" as used herein, either alone or in combination with another radical, means straight chain or branched alkyl radicals containing up to six carbon atoms and includes, for example, methyl, ethyl, propyl, butyl, hexyl, 1-methylethyl, 1-methylpropyl, 2-methylpropyl,
10 1,1-dimethylethyl.

Likewise, the terms "C₁₋₃ alkyl" "C₁₋₄ alkyl" and "C₁₋₁₀ alkyl" are used to denote alkyl radicals containing up to three, four and ten carbon atoms, respectively.

15 The term "C₃₋₇ cycloalkyl" as used herein, either alone or in combination with another radical, means a cycloalkyl radical containing from three to seven carbon atoms and includes cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl and cycloheptyl.
20

The term "C₄₋₁₀ (alkylcycloalkyl)" as used herein means a cycloalkyl radical containing from three to seven carbon atoms linked to an alkyl radical, the linked
25 radicals containing up to ten carbon atoms; for example, cyclopropylmethyl, cyclopentylethyl, cyclohexylmethyl, cyclohexylethyl or cycloheptyl-ethyl.

30 The term "C₂₋₁₀ alkenyl" as used herein, either alone or in combination with another radical, means an alkyl radical as defined above containing from 2 to 10 carbon atoms, and further containing at least one double bond. For example alkenyl includes allyl.

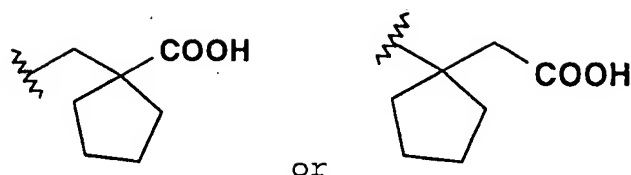
The term "C₃₋₄ alkylene" as used herein means a divalent alkyl radical derived by the removal of two hydrogen atoms from a straight or branched chain aliphatic hydrocarbon containing from three to four carbon atoms and includes, for example, -CH₂CH₂CH₂-, CH(CH₃)CH₂CH₂-, -CH₂C(CH₃)₂- and -CH₂CH₂CH₂CH₂-.

The term "C₁₋₆ alkoxy" as used herein, either alone or in combination with another radical, means the radical -O-C₁₋₆ alkyl wherein alkyl is as defined above containing up to six carbon atoms. Alkoxy includes methoxy, ethoxy, propoxy, 1-methylethoxy, butoxy and 1,1-dimethylethoxy. The latter radical is known commonly as *tert*-butoxy.

The term "C₆ or C₁₀ aryl" as used herein, either alone or in combination with another radical, means either an aromatic monocyclic system containing 6 carbon atoms or an aromatic cyclic system containing 10 carbon atoms.

The term "C₇₋₁₆ aralkyl" as used herein, either alone or in combination with another radical, means an aryl as defined above linked through an alkyl group, wherein alkyl is as defined above containing from 1 to 6 carbon atoms. Aralkyl includes for example benzyl, and butylphenyl.

The term "carboxy(lower)alkyl" as used herein, either alone or in combination with another radical, means a carboxyl group (COOH) linked through a (lower)alkyl group as defined above and includes for example butyric acid or the groups:



The term "cyclic" or "cyclic system" as used herein, either alone or in combination with another radical, means a monovalent radical derived by removal of a hydrogen from a saturated or unsaturated cyclic hydrocarbon, containing from three to seven carbon atoms, unless otherwise indicated and optionally containing one or more heteroatom. The term cyclic or cyclic system includes, for example, cyclopropane, cyclopentane, cyclohexane, cyclohexene, decalin, tetralin, indene, and naphthalene.

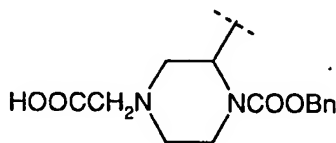
The term "heterocycle" as used herein, either alone or in combination with another radical, means a monovalent radical derived by removal of a hydrogen from a five-, six-, or seven-membered saturated or unsaturated heterocycle containing from one to four heteroatoms selected from nitrogen, oxygen and sulfur. Examples of suitable heterocycles include: pyrrolidine, tetrahydrofuran, thiazolidine, pyrrole, thiophene, diazepine, 1H-imidazole, 1-methyl-1H-imidazole, isoxazole, thiazole, 2-methylthiazole, 2-aminothiazole, piperidine, 1,4-dioxane, 4-morpholine, pyridine, 2-methylpyridine, pyrimidine, 4-methylpyrimidine and 2,4-dimethylpyrimidine.

The term "heterocyclic system" as used herein, either alone or in combination with another radical, means a heterocycle as defined above fused to one or more other cycle be it a heterocycle or any other cycle.

Examples of suitable heterocyclic systems include: thiazolo[4,5-b]-pyridine, quinoline, or indole.

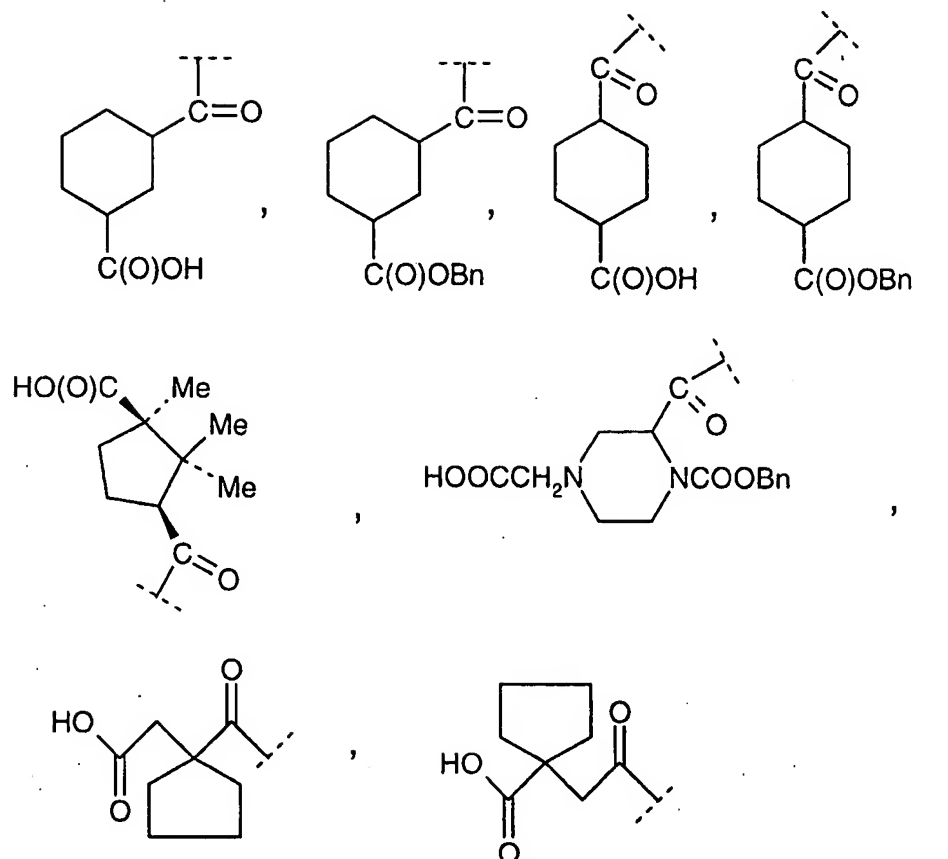
Preferred embodiments

- 5 A further preferred group of compounds are represented by formula I wherein **B** is preferably an acyl derivative of formula $R_{11}C(O)-$ wherein R_{11} is: C_{1-6} alkyl optionally substituted with carboxyl, C_{1-6} alkanoyloxy or C_{1-6} alkoxy;
- 10 C_{3-7} cycloalkyl optionally substituted with carboxyl, $MeOC(O)$, $EtOC(O)$ or $BnOC(O)$; 3-carboxypropionyl (DAD) or 4-carboxybutyryl (DAE); or

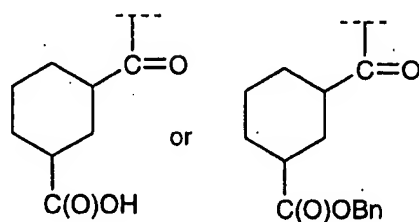


- 15 More preferably, **B** is acetyl, 3-carboxypropionyl, 4-carboxybutyryl, $AcOCH_2C(O)$, $Me_3COC(O)$,

18



Still, more preferably, **B** is acetyl, 3-carboxypropionyl (DAD), 4-carboxybutyryl (DAE),
 5 AcOCH₂C(O),



Most preferably, **B** is acetyl, or 4-carboxybutyryl (DAE). Preferably, **B** is acetyl.

10 Preferably, **R₆**, when present, is the side chain of Asp or Glu.

Most preferably, **R₆**, when present, is the side chain of Asp.

Alternatively, preferably, **a** is 0 and then **R₆** is absent.

Preferably, **R₅**, when present, is the side chain of an amino acid selected from the group consisting of: D-Asp, L-Asp, D-Glu, L-Glu, D-Val, L-Val, D-tert-butylglycine (Tbg), and L-Tbg.

More preferably, **R₅**, when present, is the side chain of D-Asp, D-Val, or D-Glu.

Most preferably, **R₅**, when present, is the side chain of D-Glu.

Alternatively, preferably **a** is 0 and **b** is 0, and then both **R₆** and **R₅** are absent.

Preferably, **Y** is H or C₁₋₃ alkyl.

More preferably, **Y** is Me.

Alternatively, more preferably **Y** is H.

Preferably, **R₄** is the side chain of an amino acid selected from the group consisting of: Val, cyclohexylglycine (Chg), Tbg, Ile, or Leu.

More preferably, **R₄** is the side chain of Chg or Ile.

Most preferably, **R₄** is the side chain of Chg.

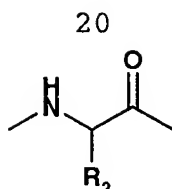
Preferably, **R₃** is the side chain of an amino acid selected from the group consisting of: Ile, Chg, Cha, Val or Glu.

More preferably, **R₃** is the side chain of Val or Chg.

Most preferably, **R₃** is the side chain of Val.

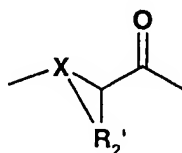
30

Preferably, **W** is a group of formula II:



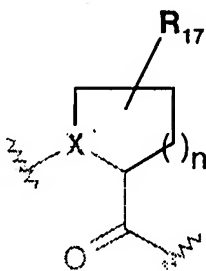
wherein R_2 is C_{1-8} alkyl or C_{3-6} cycloalkyl optionally substituted with carboxyl; or benzyl. More preferably, R_2 is the side chain of Asp, aminobutyric acid (Abu) or Val.

Still, more preferably, W is a group of formula II':



wherein preferably, X is CH or N.

More preferably R_2' is a C_3 or C_4 alkylene (shown in black) that joins X to form a 5- or 6-membered ring of formula III:



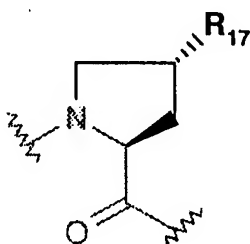
Formula III

R_2' being optionally substituted at any position with R_{17} , wherein X is CH or N; n is 1 or 2, and R_{17} is as defined below.

Most preferably, X is N. For example, preferably R_2' is propylene joined to X wherein X is nitrogen to form a proline substituted with R_{17} at P2.

Most preferably R_2' is the side chain of proline substituted at the 3-, 4-, or 5-position with R_{17} , wherein R_{17} is as defined below.

- 5 Still, most preferably R_2' is the side chain of proline (as shown in black) substituted with R_{17} at the 4-position with the stereochemistry shown in formula III':



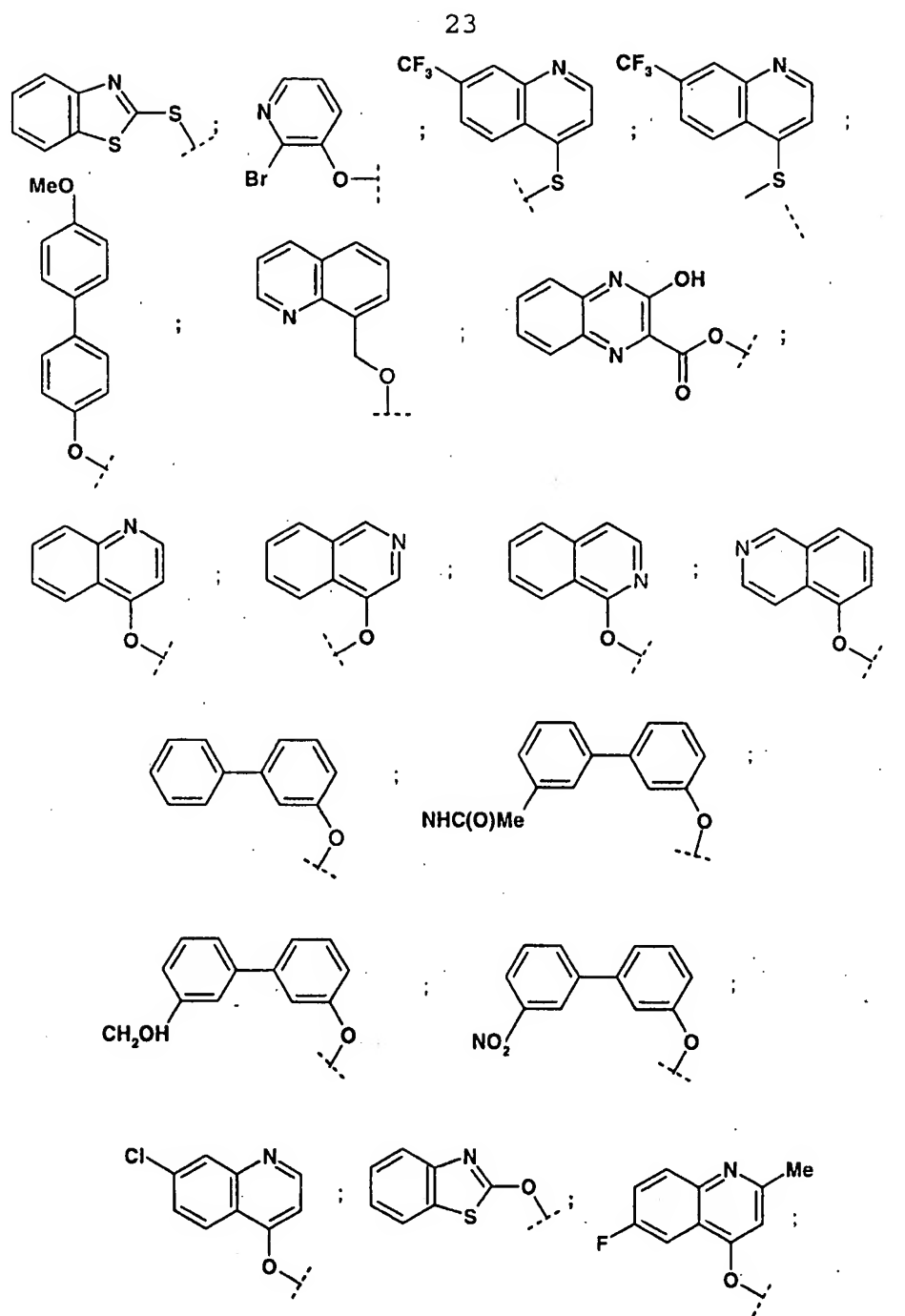
Formula III'

- 10 wherein R_{17} is preferably OH; SH; NH_2 ; carboxyl; R_{12} ; OR_{12} , SR_{12} , NHR_{12} or $NR_{12}R_{12}'$ wherein R_{12} and R_{12}' are independently:
- cyclic C_{3-16} alkyl or acyclic C_{1-16} alkyl or cyclic C_{3-16} alkenyl or acyclic C_{2-16} alkenyl,
 - 15 said alkyl or alkenyl optionally substituted with NH_2 , OH, SH, halo, or carboxyl; said alkyl or alkenyl optionally containing at least one heteroatom independently selected from the group consisting of: O, S, and N; or
 - 20 R_{12} and R_{12}' are independently C_6 or C_{10} aryl or C_{7-16} aralkyl optionally substituted with C_{1-6} alkyl, NH_2 , OH, SH, halo, carboxyl or carboxy(lower)alkyl; said aryl or aralkyl optionally containing at least one heteroatom
 - 25 independently selected from the group consisting of: O, S, and N;
 - said cyclic alkyl, cyclic alkenyl, aryl or aralkyl being optionally fused with a second 5-, 6- or 7-membered ring to form a cyclic system

or heterocycle, said second ring being optionally substituted with NH_2 , OH, SH, halo, carboxyl or carboxy(lower)alkyl; said second ring optionally containing at least one heteroatom independently selected from the group consisting of: O, S, and N.

More preferably, R_{17} is OR_{12} wherein R_{12} is a C_6 or C_{10} aryl or C_{7-16} aralkyl, said first aryl or aralkyl optionally substituted with C_{1-6} alkyl, C_{3-7} cycloalkyl, NH_2 , OH, SH, halo, C_{1-6} alkoxy, carboxyl, carboxy(lower)alkyl, or a second aryl or aralkyl; said first and second aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N.

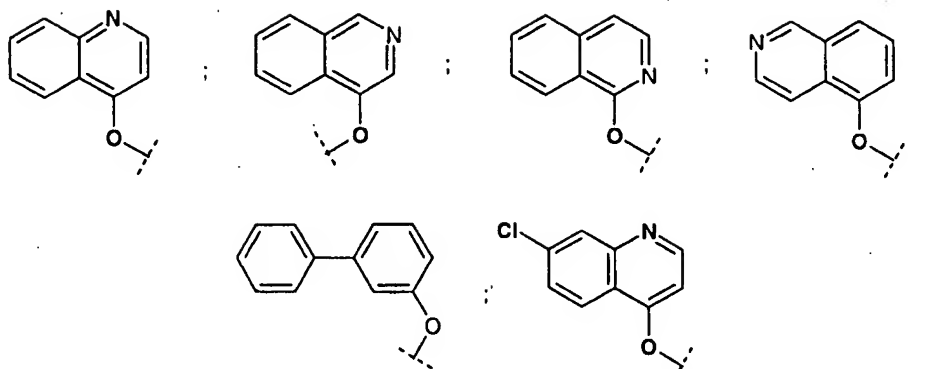
Most preferably, R_{17} is Bn; PhCH_2CH_2 ; $\text{PhCH}_2\text{CH}_2\text{CH}_2$; O-Bn; o-tolylmethoxy; m-tolylmethoxy; p-tolylmethoxy; 1-naphtyloxy; 2-naphtyloxy; 1-naphthalenylmethoxy; 2-naphthalenylmethoxy; (4-tert-butyl)methoxy; (3I-Ph) CH_2O ; (4Br-Ph) O ; (2Br-Ph) O ; (3Br-Ph) O ; (4I-Ph) O ; (3Br-Ph) CH_2O ; (3,5-Br₂-Ph) CH_2O ;



Still most preferably, R_{17} is Bn; $PhCH_2CH_2$;

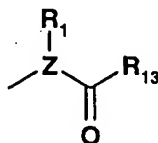
- 5 PhCH₂CH₂CH₂; O-Bn; 1-naphtyloxy; 2-naphtyloxy; 1-naphthalenylmethoxy; 2-naphthalenylmethoxy;

24



Even most preferably, R_{17} is O-Bn, 1-naphthalenylmethoxy, or 2-naphthalenylmethoxy.

Preferably Q is:



wherein Z is preferably CH or N.

10

Preferably, when Z is CH:

R_{13} is H; CF_3 ; CF_2CF_3 ; CH_2-R_{14} ; $C(O)NH-R_{14}$, $NR_{14}R_{14}$,

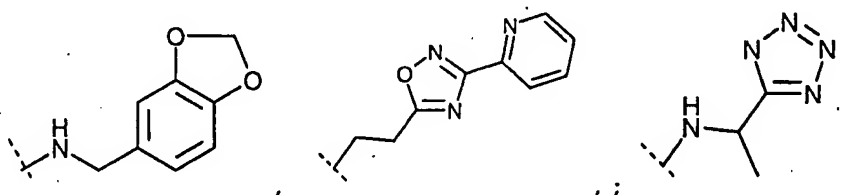
wherein R_{14} and R_{14} are as defined above with the proviso that R_{13} is not an α -amino acid or an ester

thereof. More preferably R_{13} is H; $NH-R_{14}$ or $C(O)NH-R_{14}$. Most preferably, R_{13} is H; or $C(O)NH-R_{14}$.

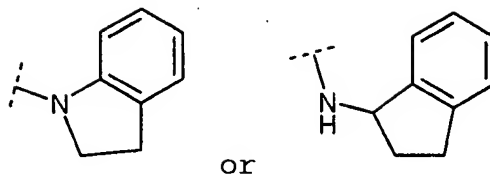
Preferably R_{14} is phenyl or C_{7-16} aralkyl. More preferably, R_{14} is benzyl or $CH(Me)Ph$.

20 Alternatively, when Z is N:

R_{13} is preferably phenyl, or C_{7-16} aralkyl,

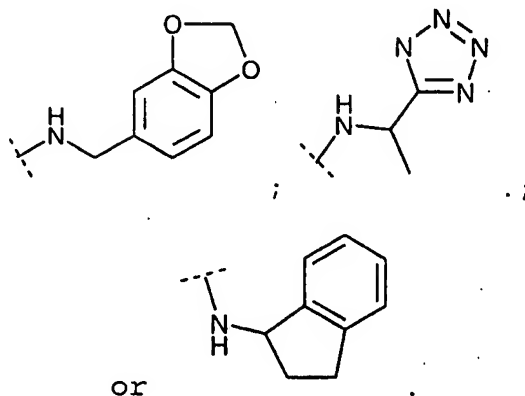


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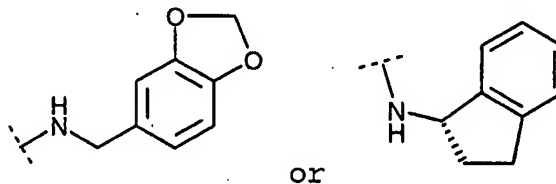


More preferably, R_{13} is naphthyl, $NH-CH(Me)Ph$, $NH-CH(Et)Ph$,

5

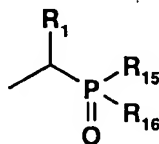


Most preferably, R_{13} is, $NH-CH(Me)Ph$, or



10

Alternatively, Q is preferably a phosphonate group of the formula:



wherein R_{15} and R_{16} are independently preferably C_6-12 aryloxy. More preferably, R_{15} and R_{16} are each phenoxy.

In all of the above cases, R_1 is preferably C_{1-6} alkyl or C_{1-6} alkenyl optionally substituted with halo.

More preferably, R_1 is C_{1-5} alkyl or C_{1-4} alkenyl optionally substituted with fluoro. Most preferably, R_1 is ethyl, propyl, isopentyl, or allyl.

5 According to an alternate embodiment, the pharmaceutical compositions of this invention may additionally comprise an antiviral agent. Examples of antiviral agents include, ribavirin and amantadine.

10

According to another alternate embodiment, the pharmaceutical compositions of this invention may additionally comprise other inhibitors of HCV protease.

15

According to yet another alternate embodiment, the pharmaceutical compositions of this invention may additionally comprise an inhibitor of other targets in the HCV life cycle, such as helicase, polymerase, or metalloprotease.

20

The pharmaceutical compositions of this invention may be administered orally, parenterally or via an implanted reservoir. We prefer oral administration or administration by injection. The pharmaceutical compositions of this invention may contain any conventional non-toxic pharmaceutically-acceptable carriers, adjuvants or vehicles. In some cases, the pH of the formulation may be adjusted with pharmaceutically acceptable acids, bases or buffers to enhance the stability of the formulated compound or its delivery form. The term parenteral as used herein includes subcutaneous, intracutaneous, intravenous, intramuscular, intra-articular,

25

30

intrasynovial, intrasternal, intrathecal, and
intralesional injection or infusion techniques.

The pharmaceutical compositions may be in the form of
5 a sterile injectable preparation, for example, as a
sterile injectable aqueous or oleaginous suspension.
This suspension may be formulated according to
techniques known in the art using suitable dispersing
or wetting agents (such as, for example, Tween 80)
10 and suspending agents.

The pharmaceutical compositions of this invention may
be orally administered in any orally acceptable
dosage form including, but not limited to, capsules,
15 tablets, and aqueous suspensions and solutions. In
the case of tablets for oral use, carriers which are
commonly used include lactose and corn starch.
Lubricating agents, such as magnesium stearate, are
also typically added. For oral administration in a
20 capsule form, useful diluents include lactose and
dried corn starch. When aqueous suspensions are
administered orally, the active ingredient is
combined with emulsifying and suspending agents. If
desired, certain sweetening and/or flavoring and/or
25 coloring agents may be added.

Other suitable vehicles or carriers for the above
noted formulations and compositions can be found in
standard pharmaceutical texts, e.g. in "Remington's
30 Pharmaceutical Sciences", The Science and Practice of
Pharmacy, 19th Ed. Mack Publishing Company, Easton,
Penn., (1995).

Dosage levels of between about 0.01 and about 100

mg/kg body weight per day, preferably between about 0.5 and about 75 mg/kg body weight per day of the protease inhibitor compounds described herein are useful in a monotherapy for the prevention and treatment of HCV mediated disease. Typically, the pharmaceutical compositions of this invention will be administered from about 1 to about 5 times per day or alternatively, as a continuous infusion. Such administration can be used as a chronic or acute therapy. The amount of active ingredient that may be combined with the carrier materials to produce a single dosage form will vary depending upon the host treated and the particular mode of administration. A typical preparation will contain from about 5% to about 95% active compound (w/w). Preferably, such preparations contain from about 20% to about 80% active compound.

As the skilled artisan will appreciate, lower or higher doses than those recited above may be required. Specific dosage and treatment regimens for any particular patient will depend upon a variety of factors, including the activity of the specific compound employed, the age, body weight, general health status, sex, diet, time of administration, rate of excretion, drug combination, the severity and course of the infection, the patient's disposition to the infection and the judgment of the treating physician. Generally, treatment is initiated with small dosages substantially less than the optimum dose of the peptide. Thereafter, the dosage is increased by small increments until the optimum effect under the circumstances is reached. In general, the compound is most desirably administered

at a concentration level that will generally afford antivirally effective results without causing any harmful or deleterious side effects.

- 5 When the compositions of this invention comprise a combination of a compound of formula I and one or more additional therapeutic or prophylactic agent, both the compound and the additional agent should be present at dosage levels of between about 10 to 100%,
10 and more preferably between about 10 and 80% of the dosage normally administered in a monotherapy regimen.

- When these compounds or their pharmaceutically
15 acceptable salts are formulated together with a pharmaceutically acceptable carrier, the resulting composition may be administered *in vivo* to mammals, such as man, to inhibit HCV NS3 protease or to treat or prevent HCV virus infection. Such treatment may
20 also be achieved using the compounds of this invention in combination with agents which include, but are not limited to: immunomodulatory agents, such as α -, β -, or γ -interferons; other antiviral agents such as ribavirin, amantadine; other
25 inhibitors of HCV NS3 protease; inhibitors of other targets in the HCV life cycle such as helicase, polymerase, metalloprotease, or internal ribosome entry; or combinations thereof. The additional agents may be combined with the compounds of this
30 invention to create a single dosage form. Alternatively these additional agents may be separately administered to a mammal as part of a multiple dosage form.

Accordingly, another embodiment of this invention provides methods of inhibiting HCV NS3 protease activity in mammals by administering a compound of the formula I, wherein the substituents are as
5 defined above.

In a preferred embodiment, these methods are useful in decreasing HCV NS3 protease activity in a mammal. If the pharmaceutical composition comprises only a
10 compound of this invention as the active component, such methods may additionally comprise the step of administering to said mammal an agent selected from an immunomodulatory agent, an antiviral agent, a HCV protease inhibitor, or an inhibitor of other targets
15 in the HCV life cycle such as helicase, polymerase, or metallo protease. Such additional agent may be administered to the mammal prior to, concurrently with, or following the administration of the compositions of this invention.

20 In an alternate preferred embodiment, these methods are useful for inhibiting viral replication in a mammal. Such methods are useful in treating or preventing HCV disease. If the pharmaceutical
25 composition comprises only a compound of this invention as the active component, such methods may additionally comprise the step of administering to said mammal an agent selected from an immunomodulatory agent, an antiviral agent, a HCV
30 protease inhibitor, or an inhibitor of other targets in the HCV life cycle. Such additional agent may be administered to the mammal prior to, concurrently with, or following the administration of the composition according to this invention.

The compounds set forth herein may also be used as laboratory reagents. The compounds of this invention may also be used to treat or prevent viral

5 contamination of materials and therefore reduce the risk of viral infection of laboratory or medical personnel or patients who come in contact with such materials (e.g. blood, tissue, surgical instruments and garments, laboratory instruments and garments,

10 and blood collection apparatuses and materials).

PROCESS

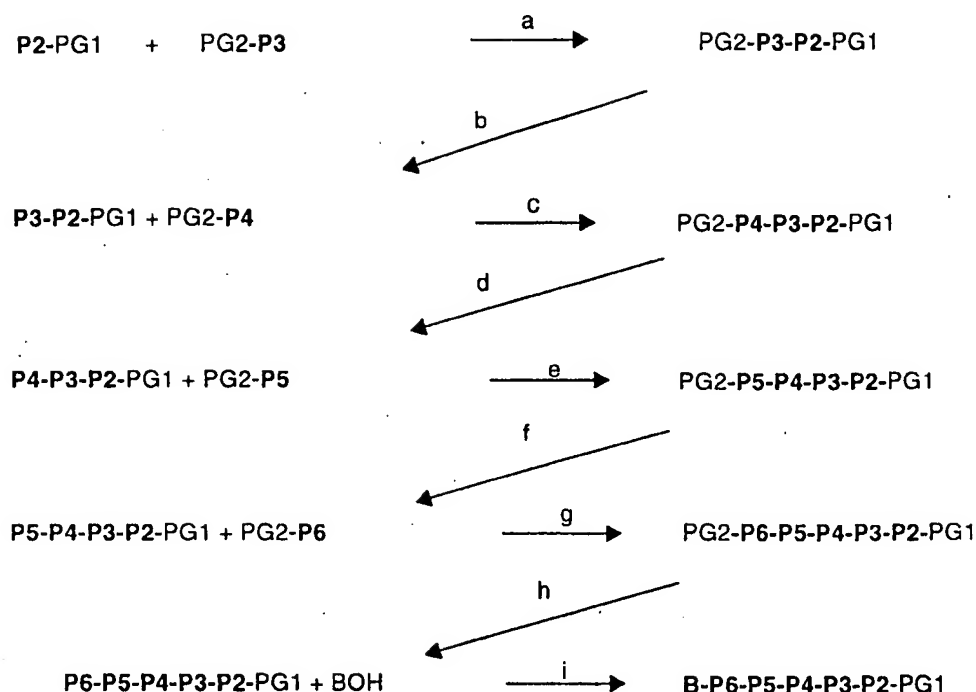
Synthesis of P6-P2 fragments

The P2-P6 fragments of the compounds of the present

15 invention were synthesized according to the process as illustrated in scheme I (wherein PG1 is a carboxyl protecting group and PG2 is an amino protecting group):

32

Scheme I



Briefly, the P2, P3, P4, and optionally P5 and P6 can be linked by well known peptide coupling techniques.

- 5 The P2, P3, P4, and P5 and P6 moieties may be linked together in any order as long as the final compound corresponds to peptides of formula I. For example, P6 can be linked to P5 to give P5-P6 that is linked to P4-P3-P2; or P6 linked to P5-P4-P3 then linked to an
- 10 appropriately C-terminal protected P2.

- Generally, peptides are elongated by deprotecting the α -amino group of the N-terminal residue and coupling the unprotected carboxyl group of the next suitably
- 15 N-protected amino acid through a peptide linkage using the methods described. This deprotection and coupling procedure is repeated until the desired sequence is obtained. This coupling can be performed with the constituent amino acids in stepwise fashion,

as depicted in Scheme I, or by condensation of fragments (two or several amino acids), or combination of both processes, or by solid phase peptide synthesis according to the method originally
5 described in Merrifield, J. Am. Chem. Soc., (1963), 85, 2149-2154, the disclosure of which is hereby incorporated by reference.

Coupling between two amino acids, an amino acid and a
10 peptide, or two peptide fragments can be carried out using standard coupling procedures such as the azide method, mixed carbonic-carboxylic acid anhydride (isobutyl chloroformate) method, carbodiimide (dicyclohexylcarbodiimide, diisopropylcarbodiimide,
15 or water-soluble carbodiimide) method, active ester (p-nitrophenyl ester, N-hydroxysuccinic imido ester) method, Woodward reagent K-method, carbonyldiimidazole method, phosphorus reagents or oxidation-reduction methods. Some of these methods
20 (especially the carbodiimide method) can be enhanced by adding 1-hydroxybenzotriazole. These coupling reactions can be performed in either solution (liquid phase) or solid phase.

25 More explicitly, the coupling step involves the dehydrative coupling of a free carboxyl of one reactant with the free amino group of the other reactant in the presence of a coupling agent to form a linking amide bond. Description of such coupling
30 agents are found in general textbooks on peptide chemistry, for example, M. Bodanszky, "Peptide Chemistry", 2nd rev ed., Springer-Verlag, Berlin, Germany, (1993). Examples of suitable coupling agents are *N,N'*-dicyclohexylcarbodiimide, 1-

hydroxybenzotriazole in the presence of *N,N'*-dicyclohexylcarbodiimide or *N*-ethyl-*N'*-[(3-dimethylamino)propyl]carbodiimide. A very practical and useful coupling agent is the commercially available (benzotriazol-1-yloxy)tris-(dimethylamino)phosphonium hexafluorophosphate, either by itself or in the presence of 1-hydroxybenzotriazole. Another very practical and useful coupling agent is commercially available 2-(1*H*-benzotriazol-1-yl)-*N, N, N', N'*-tetramethyluronium tetrafluoroborate. Still another very practical and useful coupling agent is commercially available *O*-(7-azabenzotriazol-1-yl)-*N, N, N', N'*-tetramethyluronium hexafluorophosphate.

15

The coupling reaction is conducted in an inert solvent, e.g. dichloromethane, acetonitrile or dimethylformamide. An excess of a tertiary amine, e.g. diisopropylethylamine, *N*-methylemorpholine or *N*-methylpyrrolidine, is added to maintain the reaction mixture at a pH of about 8. The reaction temperature usually ranges between 0°C and 50°C and the reaction time usually ranges between 15 min and 24 h.

25

When a solid phase synthetic approach is employed, the C-terminal carboxylic acid is attached to an insoluble carrier (usually polystyrene). These insoluble carriers contain a group that will react with the carboxylic group to form a bond that is stable to the elongation conditions but readily cleaved later. Examples of which are: chloro- or bromomethyl resin, hydroxymethyl resin, and aminomethyl resin. Many of these resins are commercially available with the desired C-terminal

30

amino acid already incorporated. In addition to the foregoing, other methods of peptide synthesis are described in Stewart and Young, "Solid Phase Peptide Synthesis", 2nd ed., Pierce Chemical Co., Rockford, IL (1984); Gross, Meienhofer, Udenfriend, Eds., "The Peptides: Analysis, Synthesis, Biology", Vol. 1, 2, 3, 5, and 9, Academic Press, New-York, (1980-1987); Bodansky et al., "The Practice of Peptide Synthesis" Springer-Verlag, New-York (1984), the disclosures of which are hereby incorporated by reference.

The functional groups of the constituent amino acids generally must be protected during the coupling reactions to avoid formation of undesired bonds. The protecting groups that can be used are listed in Greene, "Protective Groups in Organic Chemistry", John Wiley & Sons, New York (1981) and "The Peptides: Analysis, Synthesis, Biology", Vol. 3, Academic Press, New York (1981), the disclosures of which are hereby incorporated by reference.

The α -carboxyl group of the C-terminal residue is usually protected as an ester (PG1) that can be cleaved to give the carboxylic acid. Protecting groups that can be used include: 1) alkyl esters such as methyl, trimethylsilylethyl and t-butyl, 2) aralkyl esters such as benzyl and substituted benzyl, or 3) esters that can be cleaved by mild base treatment or mild reductive means such as trichloroethyl and phenacyl esters.

The α -amino group of each amino acid to be coupled to the growing peptide chain must be protected (PG2). Any protecting group known in the art can be used.

Examples of such groups include: 1) acyl groups such as formyl, trifluoroacetyl, phthalyl, and *p*-toluenesulfonyl; 2) aromatic carbamate groups such as benzyloxycarbonyl (Cbz or Z) and substituted
5 benzyloxycarbonyls, and 9-fluorenylmethyloxycarbonyl (Fmoc); 3) aliphatic carbamate groups such as *tert*-butyloxycarbonyl (Boc), ethoxycarbonyl, diisopropylmethoxycarbonyl, and allyloxycarbonyl; 4) cyclic alkyl carbamate groups such as
10 cyclopentyloxycarbonyl and adamantyloxycarbonyl; 5) alkyl groups such as triphenylmethyl and benzyl; 6) trialkylsilyl such as trimethylsilyl; and 7) thiol containing groups such as phenylthiocarbonyl and dithiasuccinoyl. The preferred α -amino protecting
15 group is either Boc or Fmoc. Many amino acid derivatives suitably protected for peptide synthesis are commercially available.

The α -amino protecting group of the newly added amino
20 acid residue is cleaved prior to the coupling of the next amino acid. When the Boc group is used, the methods of choice are trifluoroacetic acid, neat or in dichloromethane, or HCl in dioxane or in ethyl acetate. The resulting ammonium salt is then
25 neutralized either prior to the coupling or *in situ* with basic solutions such as aqueous buffers, or tertiary amines in dichloromethane or acetonitrile or dimethylformamide. When the Fmoc group is used, the reagents of choice are piperidine or substituted
30 piperidine in dimethylformamide, but any secondary amine can be used. The deprotection is carried out at a temperature between 0°C and room temperature (RT).

Any of the amino acids having side chain functionalities must be protected during the preparation of the peptide using any of the above-described groups. Those skilled in the art will appreciate that the selection and use of appropriate protecting groups for these side chain functionalities depend upon the amino acid and presence of other protecting groups in the peptide. The selection of such protecting groups is important in that the group must not be removed during the deprotection and coupling of the α -amino group.

For example, when Boc is used as the α -amino protecting group, *p*-toluenesulfonyl (tosyl) is suitable to protect the amino side chain of amino acids such as Lys and Arg; acetamidomethyl, benzyl (Bn), or *t*-butylsulfonyl moieties can be used to protect the sulfide containing side chain of cysteine; benzyl (Bn) ethers can be used to protect the hydroxy containing side chains of serine, threonine or hydroxyproline; and benzyl esters can be used to protect the carboxy containing side chains of aspartic acid and glutamic acid.

When Fmoc is chosen for the α -amine protection, usually *tert*-butyl based protecting groups are acceptable. For instance, Boc can be used for lysine and arginine, *tert*-butyl ether for serine, threonine and hydroxyproline, and *tert*-butyl ester for aspartic acid and glutamic acid. Triphenylmethyl (Trityl) moiety can be used to protect the sulfide containing side chain of cysteine.

Once the elongation of the peptide is completed all of the protecting groups are removed. When a liquid phase synthesis is used, the protecting groups are removed in whatever manner is dictated by the choice of protecting groups. These procedures are well known to those skilled in the art.

When a solid phase synthesis is used, the peptide is cleaved from the resin simultaneously with the removal of the protecting groups. When the Boc protection method is used in the synthesis, treatment with anhydrous HF containing additives such as dimethyl sulfide, anisole, thioanisole, or *p*-cresol at 0°C is the preferred method for cleaving the peptide from the resin. The cleavage of the peptide can also be accomplished by other acid reagents such as trifluoromethanesulfonic acid/ trifluoroacetic acid mixtures. If the Fmoc protection method is used the N-terminal Fmoc group is cleaved with reagents described earlier. The other protecting groups and the peptide are cleaved from the resin using solution of trifluoroacetic acid and various additives such as anisole, etc.

25 Synthesis of capping group B and P6, P5, P4, and P3 moieties

Different capping groups B are introduced to protected P6, P5, P4, the whole peptide or to any peptide segment with an appropriate acyl chloride that is either available commercially or for which the synthesis is well known in the art.

Different P6 to P3 moieties are available commercially or the synthesis is well known in the art.

Synthesis of P2 moieties

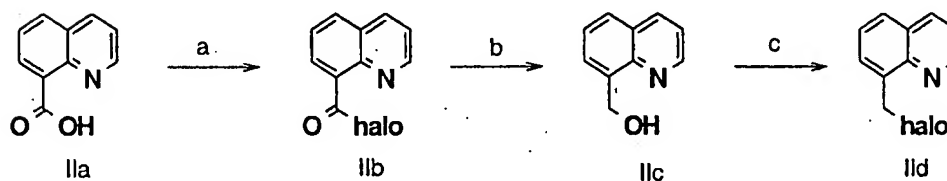
1. Synthesis of precursors:

5 A) Synthesis of haloarylmethane derivatives.

The preparation of halomethyl-8-quinoline **IIId** was done according to the procedure of K.N. Campbell et al., J. Amer. Chem. Soc., (1946), 68, 1844.

10

Scheme II



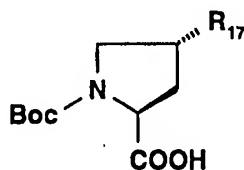
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Briefly, 8-quinoline carboxylic acid **IIa** was converted to the corresponding alcohol **IIc** by reduction of the corresponding acyl halide **IIb** with a reducing agent such as lithium aluminium hydride. Treatment of alcohol **IIb** with the appropriate hydrohaloacid gives the desired halo derivative **IIId**. A specific embodiment of this process is presented in Example 1.

20

2. Synthesis of P2:

A) The synthesis of 4-substituted proline (wherein R_{17} is attached to the ring via a carbon atom) (with
25 the stereochemistry as shown):

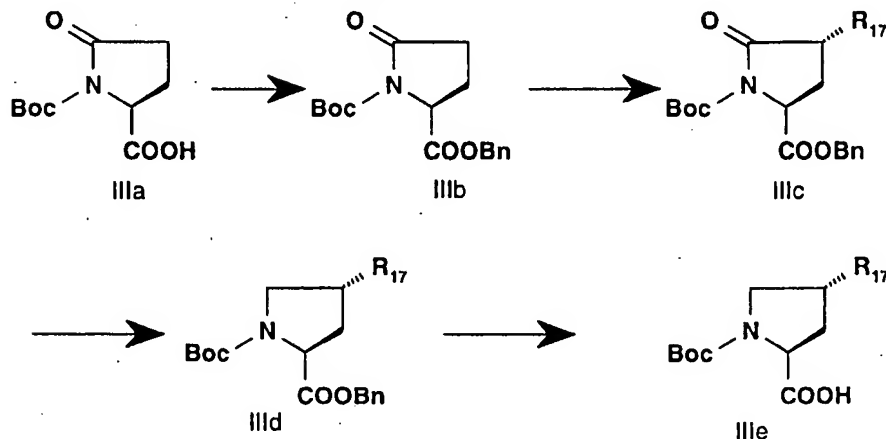


is done as shown in Scheme III according to the procedures described by J. Ezquerro et al.

40

(Tetrahedron, (1993), 38, 8665-8678) and C. Pedregal et al. (Tetrahedron Lett., (1994), 35, 2053-2056).

Scheme III

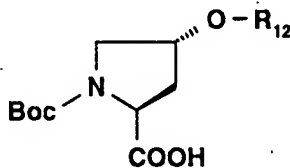


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Briefly, Boc-pyroglutamic acid is protected as a benzyl ester. Treatment with a strong base such as lithium diisopropylamide followed by addition of an alkylating agent (Br-R_{17} or I-R_{17}) gives the desired compounds **IIIe** after reduction of the amide and deprotection of the ester. A specific embodiment of this process is presented in Example 2.

10

15 B) The synthesis of O-alkylated 4-(*R*)-hydroxyproline:



may be carried out using the different processes described below.

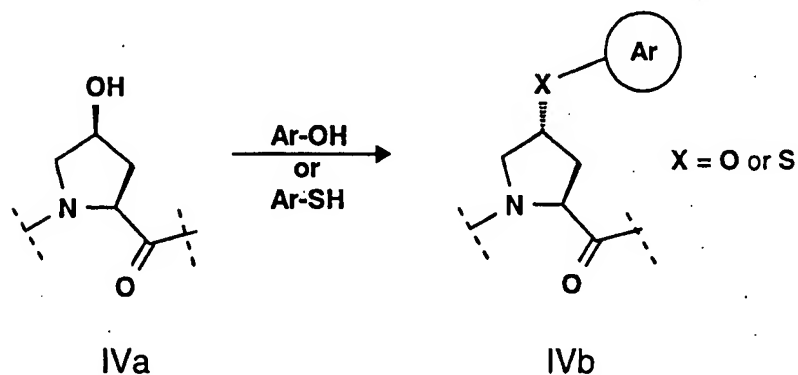
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B.1) When R_{12} is aralkyl, the process can be carried out according to the procedure described by E.M. Smith et al. (J. Med. Chem. (1988), 31, 875-885). Briefly, commercially available Boc-

4(R)-hydroxyproline is treated with a base such as sodium hydride and the resulting alkoxide reacted with an alkylating agent (Br-R_{12} or I-R_{12}) to give the desired compounds. Specific
5 embodiments of this process are presented in Examples 3 and 4.

B.2) When R_{12} is aryl, the compounds can be prepared via a Mitsunobu reaction (Mitsunobu
10 (1981), *Synthesis*, January, 1-28; Rano et al., (1995), *Tet. Lett.* 36(22), 3779-3792; Krchnak et al., (1995), *Tet. Lett.* 36(5), 62193-6196; Richter et al., (1994), *Tet. Lett.* 35(27), 4705-4706). Briefly, commercially available Boc-
15 4(S)-hydroxyproline methyl ester is treated with the appropriate aryl alcohol or thiol in the presence of triphenylphosphine and diethylazodicarboxylate (DEAD) and the resulting ester is hydrolysed to the acid. Specific
20 embodiment of this process are presented in Example 5.

Scheme IV

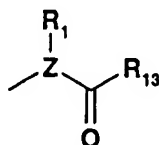


25 Alternatively, the Mitsunobu reaction can be performed on solid phase (as shown in Scheme IV). The 96-well block of the Model 396 synthesizer

(advanced ChemTech) is provided with aliquots of resin-bound compound (IVa) and a variety of aryl alcohols or thiols and appropriate reagents are added. After incubation, each resin-bound product (IVb) is washed, dried, and cleaved from the resin.

B.2.a) A Suzuki reaction (Miyaura et al., (1981), Synth. Comm. 11, 513; Sato et al., (1989), Chem. Lett., 1405; Watanabe et al., (1992), Synlett., 207; Takayuki et al., (1993), J. Org. Chem. 58, 2201; Frenette et al., (1994), Tet. Lett. 35(49), 9177-9180; Guiles et al., (1996), J. Org. Chem. 61, 5169-5171) can also be used to further functionalize the aryl substituent.

C) Synthesis of compounds of formula I wherein Q is:



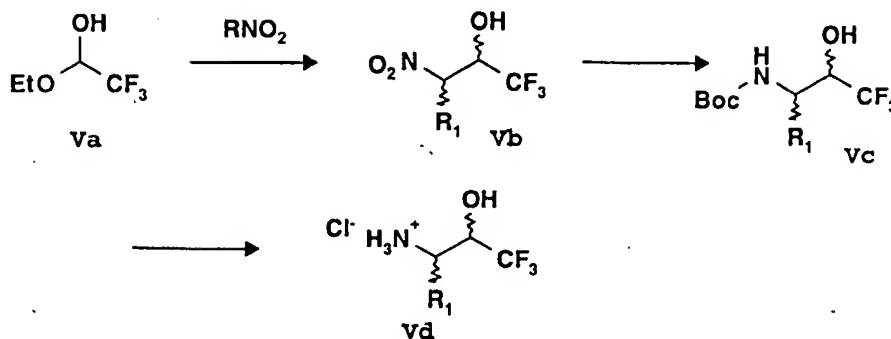
wherein Z is CH; R₁ is as defined above and R₁₃ is CF₃, CF₂CF₃ or C(O)NH-R₁₄; was done as described in Scheme VIII.

The synthesis of the required P1 moieties was done as follows:

i) For the synthesis of trifluoromethyl alcohols of formula Vd the procedure described by J.W. Skiles et al. (J. Med. Chem. (1992), 35, 641-662) was used as illustrated:

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Scheme V

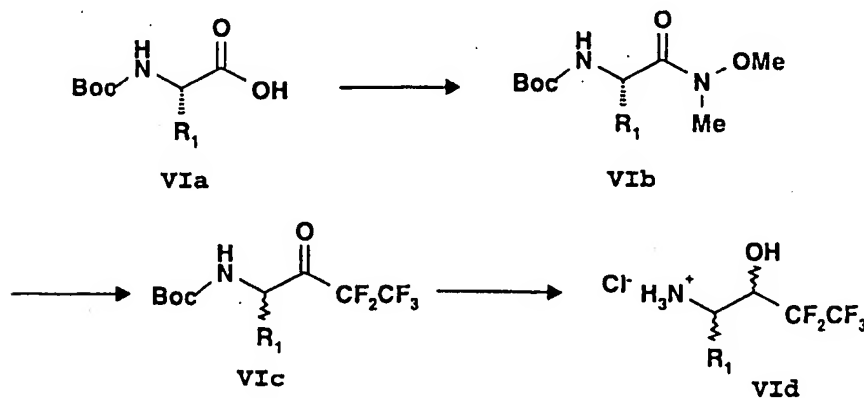


wherein R_1 is as defined above.

- 5 Briefly, a condensation between commercially available trifluoroacetaldehyde ethyl hemiacetal **Va** and the appropriate nitroalkane affords the corresponding nitroalcohol **Vb**. The nitro group was reduced (preferably with Ra-Ni) and protected as the
- 10 Boc-derivative **Vc** to allow easier purification of the fragment. Treatment of the Boc-amine with anhydrous HCl affords the hydrochloride salt **Vd**.

- ii) For the synthesis of pentafluoroethyl alcohols of
- 15 formula **VId**, the procedure described by M.R. Angelastro et al. (J. Med. Chem., (1994), 37, 4538-4554) was used as illustrated in scheme VI:

Scheme VI

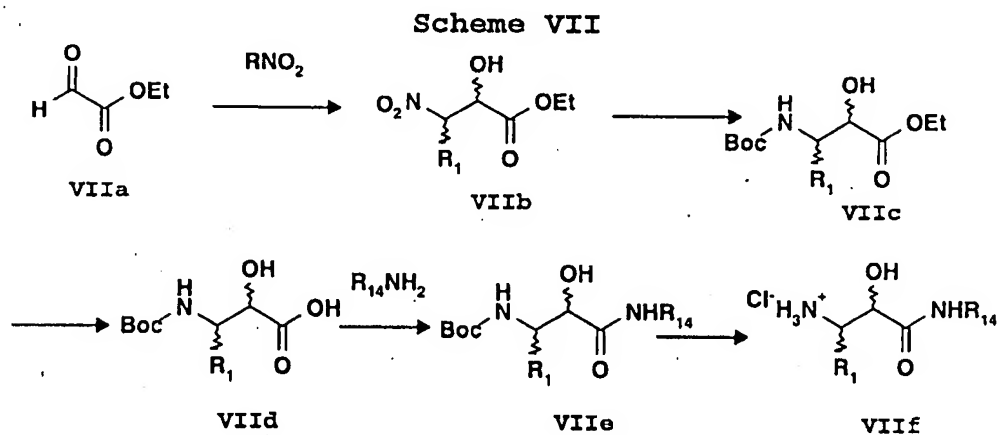


- 20 wherein R_1 is as defined above.

Briefly, the Boc-amino acid **VIa** was converted to the Weinreb amide **VIb** according to the procedure described by Castro, B. et al. (Synthesis, (1983), 676-678) and treated with lithium pentafluoroethane.

5 The resulting pentafluoroethyl ketone **VIc** was reduced and the Boc protecting group removed with anhydrous HCl to give the hydrochloride salt of the desired amino alcohol **VIId**.

10 iii) For the synthesis of hydroxy amides of formula **VIIf** the procedure described by Peet et al. (Tet. Lett. (1988), 3433) was used as illustrated in scheme VII:



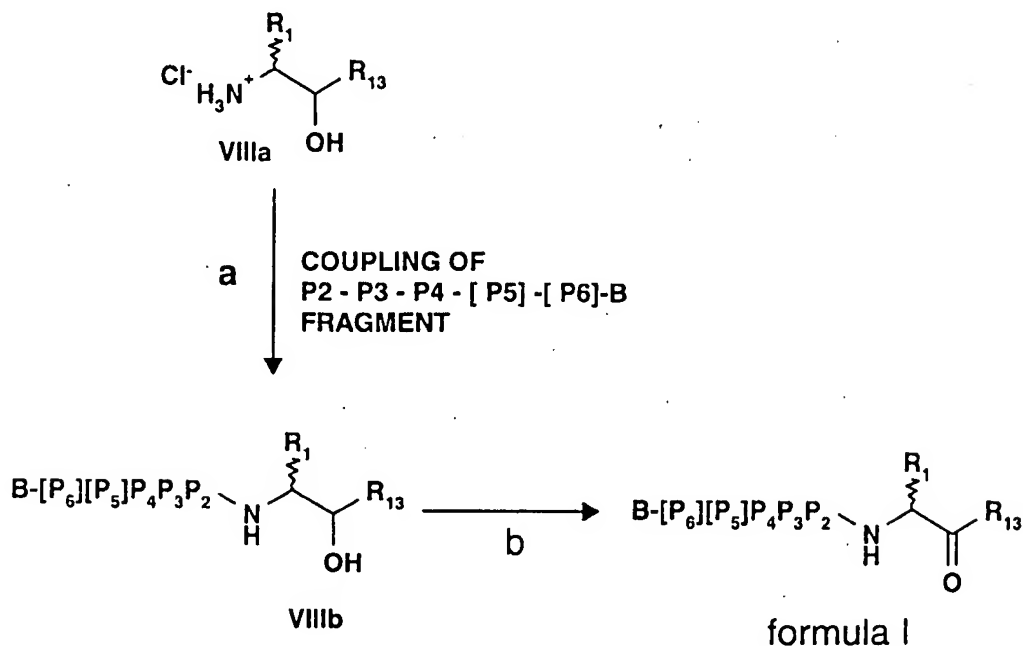
wherein R_1 is as defined above.

Briefly, condensation between ethyl glyoxylate **VIIa** and a nitroalkane under basic conditions afforded the corresponding nitroalcohol **VIIf**. The nitro group was reduced (preferably with Ra-Ni) and protected as the Boc-derivative **VIIc**. Saponification of the ester group followed by standard coupling with an amine gave the hydroxy amide **VIIe**. Removal of the Boc protecting group with anhydrous HCl afforded the

hydrochloride salt of the desired amino hydroxyamide **VIIIf**.

- iv) The coupling to P2-P6 was carried out as
5 illustrated in scheme VIII:

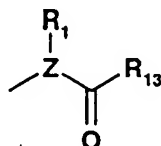
Scheme VIII



- 10 a) The P6 to P2 fragment can be linked to the free amino group of the amino alcohol derivative **VIIIa** as described previously in Scheme I to give the peptido alcohol **VIIIb**.
- 15 b) The alcohol functionality of the peptido alcohol **VIIIb** is then oxidized by techniques and procedures well known and appreciated by one of ordinary skill in the art, such as the Swern Oxidation (Tidwell, T.T., Synthesis, (1990), 857-870), or more
- 20 specifically the Pfitzner-Moffatt oxidation (K. E. Pfitzner, and J. G. Moffatt, J. Am. Chem. Soc., (1965), 5670-5678) and the Dess-Martin periodinane method (D. B. Dess or J.C. Martin, (J. Org. Chem.,

(1983), 48, 4155-4156) to give the compounds of formula I wherein Q contains an activated carbonyl.

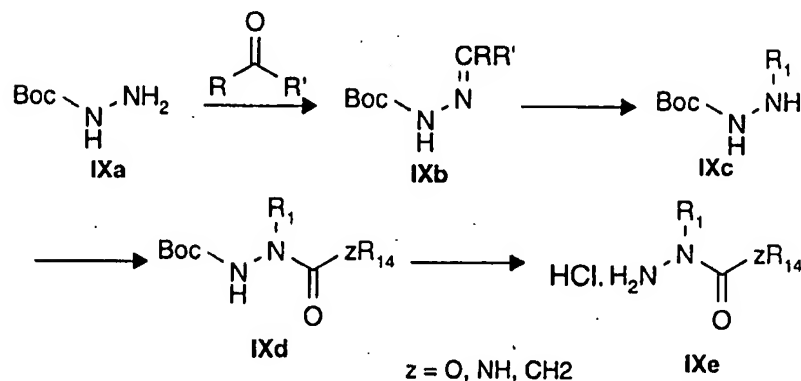
D) Synthesis of compounds of formula I wherein Q is:



wherein Z is N; and R₁₃ is NHR₁₄, NR₁₄R₁₄', CH₂-R₁₄, CHR₁₄R₁₄' or O-R₁₄; wherein R₁₄ and R₁ are as defined above, was done as described in scheme X.

10 i) For the synthesis of the aza-containing P1 fragments, the procedure described by A. S. Dutta et al. (J. Chem. Soc. Perkin I, (1975), 1712) was followed as illustrated:

15. Scheme IX



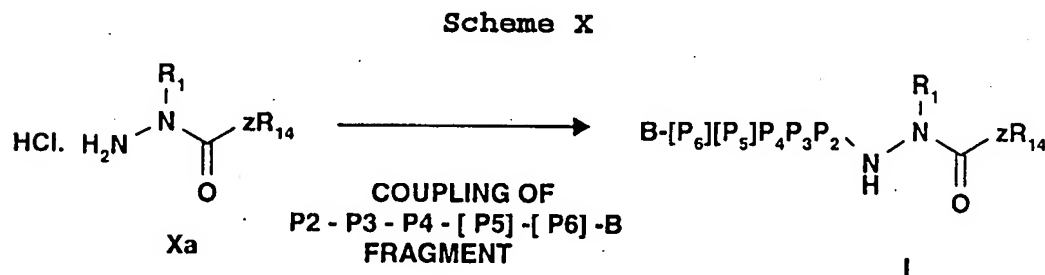
wherein R_1 and R_{14} are as defined hereinabove.

Briefly, commercially available Boc hydrazine **IXa** was
20 treated with an appropriate aldehyde or ketone to
afford the corresponding hydrazone **IXb**. The hydrazone
was reduced (preferentially with DIBAL) to give the
alkyl carbazate **IXc**. Treatment of the alkyl carbazate
with isocyanates affords the corresponding aza
25 peptide fragment (**IXd**, wherein z=NH). Treatment of

the alkyl carbozate with carbamoyl chlorides afford the corresponding aza peptide fragment (**IXd**, wherein $z=NR_{14}R_{14'}$). Treatment of the alkyl carbazate with chloroformates afford the aza-carbamate (**IXd**, wherein $z=O$) while treatment with acid chlorides affords the carbon analogues (**IXd**, wherein $z=CH_2$).

Alternatively, treatment of the alkyl carbazate with carboxylic acids using standard coupling conditions affords the corresponding aza peptide fragment (**IXd**, wherein $Z = CHR_{14'}$ or CH_2). Finally the Boc-protecting group was removed with anhydrous HCl to give the desired aza-derivatives **IXe**.

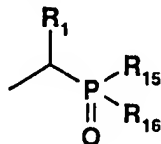
ii) Coupling of P2-P6 was carried out according to scheme X:



wherein z is O, NH, CH_2 , $CHR_{14'}$ or $NR_{14'}$.

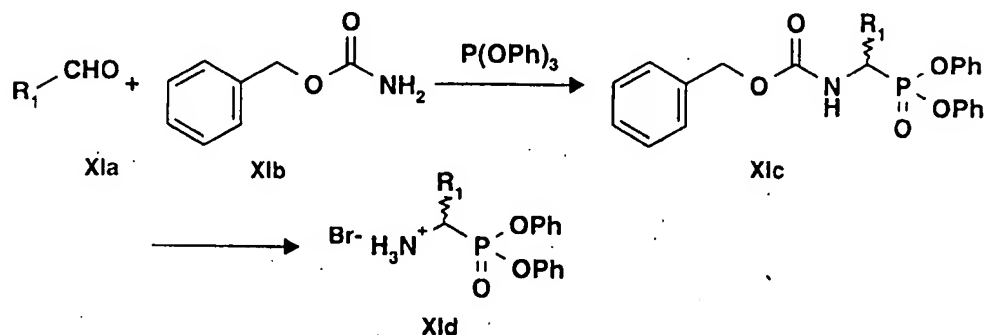
The P6 to P2 fragment can be linked to the free amino group of derivative **Xa** as described previously in Scheme I to give the aza-derivatives of formula I wherein z is N.

E) Synthesis of compounds of formula I wherein Q is:



wherein R_{15} and R_{16} are as defined above, the procedure described by J. Oleksyszyn et al. (Synthesis, (1979), 985-986) was used as illustrated in scheme XI:

Scheme XI



wherein R_1 is as defined hereinabove.

10 Briefly, a two step synthesis of the diphenyl ester was accomplished by condensation of a suitable aldehyde **XIa**, benzyl carbamate **XIb**, and triphenyl phosphite in the presence of acetic acid. Removal of the benzyloxycarbonyl protecting group of **XIc** using HBr/AcOH afforded the desired hydrobromide salt **XId**.

15

The P6 to P2 fragment can be linked to the free amino group of phosphonate derivative of formula **XId** as described previously in Scheme I to give the phosphono-peptide of formula I wherein Q is a phosphonate moiety.

The following examples are provided to describe the invention in further detail. These examples, which set forth the best mode presently contemplated for carrying out the invention, are intended to illustrate and not to limit the invention.

Examples

The present invention is illustrated in further detail by the following non-limiting examples.

Temperatures are given in degrees Celsius (°C).

5 Solution percentages express a weight to volume relationship, and solution ratios express a volume to volume relationship, unless stated otherwise. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker 400 MHz spectrometer; the
10 chemical shifts (δ) are reported in parts per million. Flash chromatography was carried out on silica gel (SiO₂) according to Still's flash chromatography technique (W.C. Still et al., J. Org. Chem., (1978), 43, 2923).

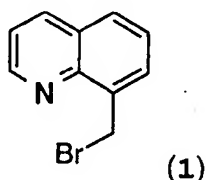
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Abbreviations used in the examples include Bn: benzyl; Boc: *tert*-butyloxycarbonyl {Me₃COC(O)}; BSA: bovine serum albumin; CHAPS: 3-[(3-cholamidopropyl)-dimethylammonio]-1-propanesulfonate; DBU: 1,8-
20 diazabicyclo[5.4.0]undec-7-ene; CH₂Cl₂= DCM: methylene chloride; DIAD: Diisopropyl azodicarboxylate; DIPEA: diisopropylethylamine; DMAP: dimethylaminopyridine; DCC: 1,3-dicyclohexylcarbodiimide; DME: 1,2-dimethoxyethane; DMF:
25 dimethylformamide; DMSO: dimethylsulfoxide; DTT: dithiothreitol or threo-1,4-dimercapto-2,3-butanediol; EDTA: ethylenediaminetetraacetic acid; Et: ethyl; EtOH: ethanol; EtOAc: ethyl acetate; Et₂O: diethyl ether; HPLC: high performance liquid
30 chromatography; MS: mass spectrometry (MALDI-TOF: Matrix Assisted Laser Desorption Ionisation-Time of Flight, FAB: Fast Atom Bombardment); LAH: lithium aluminum hydride; Me: methyl; MeOH: methanol; MES: (2-(*N*-morpholino)ethane-sulfonic acid); NaHMDS:

sodium bis(trimethylsilyl)amide; NMM: *N*-methylmorpholine; NMP: *N*-methylpyrrolidine; Pr: propyl; Succ: 4-hydroxy-1,4-dioxobutyl; PNA: 4-nitrophenylamino or *p*-nitroanalide; TBAF: tetra-*n*-butylammonium fluoride; TCEP: tris(2-carboxyethyl)phosphine hydrochloride; TFA: trifluoroacetic acid; THF: tetrahydrofuran; TIS: triisopropylsilane; TLC: thin layer chromatography; TMSE: trimethylsilylethyl; Tris/HCl: tris(hydroxymethyl)aminomethane hydrochloride.

Example 1

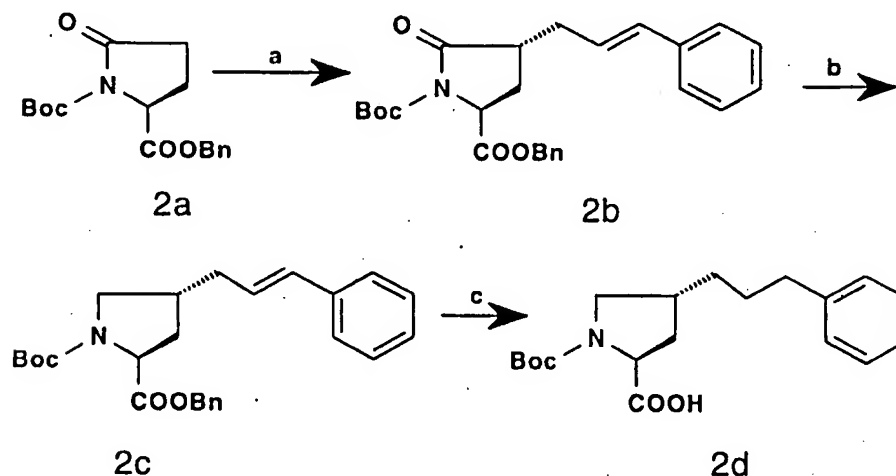
Synthesis of bromomethyl-8-quinoline (1):



To commercially available 8-quinoline carboxylic acid (2.5 g, 14.4 mmol) was added neat thionyl chloride (10 ml, 144 mmol). This mixture was heated at 80°C for 1 h before the excess thionyl chloride was distilled off under reduced pressure. To the resulting brownish solid was added absolute EtOH (15 mL) which was heated at 80°C for 1 h before being concentrated *in vacuo*. The residue was partitioned between EtOAc and saturated aqueous NaHCO₃, and the organic phase dried (MgSO₄), filtered and concentrated to give a brownish oil (2.8 g). This material (ca. 14.4 mmol) was added dropwise over 35 min to a LAH (0.76 g, 20.2 mmol)/Et₂O suspension which was cooled to -60°C. The reaction mixture was slowly warmed to -35°C over 1.5 h before the reaction was complete. The reaction was quenched with MgSO₄·10H₂O slowly over 30 min and then wet THF. The

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mixture was partitioned between Et₂O and 10% aqueous NaHCO₃. The organic phase was dried (MgSO₄), filtered and concentrated to give a yellowish solid (2.31 g, 80% over 2 steps) corresponding to the alcohol. The alcohol (2.3 g, 11.44 mmol) was dissolved in AcOH/HBr (20 mL, 30% solution from Aldrich) and heated at 70°C for 2.5 h. The mixture was concentrated in vacuo to dryness, partitioned between EtOAc (100 mL) and saturated aqueous NaHCO₃ before being dried (MgSO₄), filtered and concentrated to give the desired compound (1) as a brownish solid (2.54 g, 100%).

Example 2**Synthesis of Boc-4(R)-(3-phenylpropyl)proline (2d).****a) Synthesis of compound 2b:**

To a solution of Boc-pyrroglutamic acid benzyl ester (2a) (prepared as described by A.L Johnson et al., J. Med. Chem. (1985), 28, 1596-1602) (500 mg, 1.57 mmol) in THF (10 mL) at -78°C, was slowly added lithium hexamethyldisilylazide (1.72 mL, 1M solution in THF). After stirring for 1 h at -78°C, cinnamyl bromide (278 µL, 1.88 mmol) was added and the stirring continued for an additional 2 h. The reaction

mixture was quenched with saturated ammonium chloride solution and extracted with ethyl ether (3 x 20 mL). The combined organic extracts were dried (MgSO₄), filtered and concentrated. The residue was purified
5 by flash column chromatography (8:2 hexane:ethyl acetate) to give compound **2b** as an off-white solid (367 mg, 54% yield). ¹H NMR (CDCl₃): δ 7.35-7.19 (m, 10H), 6.43 (d, J=15 Hz, 1H), 6.11 (ddd, J=15, J'=J''=8 Hz, 1 H), 5.26 (d, J=16 Hz, 1H), 5.17 (d, J=16 Hz,
10 1H), 4.59 (dd, J=9.5, J'=2 Hz, 1 H), 2.83-2.70 (m, 2H), 2.41-2.34 (m, 1H), 2.22-2.16 (m, 1H), 2.10-2.02 (m, 1H) 1.42 (s, 9 H).

b) Synthesis of compound 2c:

15 At -78°C, lithium triethylborohydride (1M solution in THF, 1.01 mL, 1.01 mmol) was added to a solution of compound **2b** (367 mg, 0.843 mmol) in THF (5 mL), under a nitrogen atmosphere. After 30 min, the reaction mixture was quenched with saturated aqueous NaHCO₃ (2
20 mL) and warmed to 0°C. 30% H₂O₂ (5 drops) was added and the mixture was stirred at 0°C for 20 min. The organic volatiles were removed in vacuo, and the aqueous layer was extracted with CH₂Cl₂ (3 x 10 mL). The combined organic extracts were dried (MgSO₄),
25 filtered and concentrated. To a cold (-78°C) solution of the residue and triethylsilane (134 µL, 0.843 mmol) in CH₂Cl₂ (3 mL) boron trifluoride etherate (118 µL, 0.927 mmol) was added dropwise under an atmosphere of nitrogen. After 30 min, additional triethylsilane
30 (134 µL) and boron trifluoride etherate (118 µL) were added. After stirring for 2 h at -78°C, the reaction mixture was quenched with saturated aqueous NaHCO₃ (2 mL) and extracted with DCM (3 x 10 mL). The combined organic extracts were dried (MgSO₄), filtered and

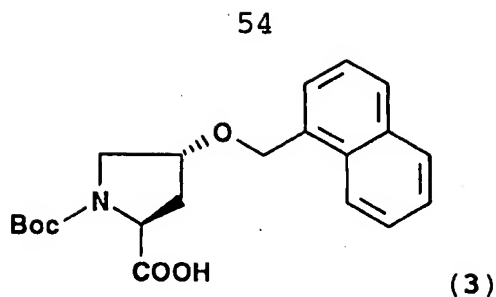
concentrated. The crude product was purified by flash column chromatography (8:2 hexane:ethyl acetate) to give compound **2c** as a colorless oil (140 mg, 40% yield). ^1H NMR (CDCl_3) indicated the presence of two rotamers: δ 7.34-7.22 (m, 10H), 6.38 (d, $J=15.5$ Hz, 1H), 6.15-6.08 (m, 1H), 5.29-5.07 (m, 2H), 4.44 (d, $J=7$ Hz, 1/3H), 4.33 (d, $J=7$ Hz, 2/3H), 3.76 (dd, $J=10.5$, $J'=8.5$ Hz, 2/3H), 3.69 (dd, $J=10.5$, $J'=8.5$ Hz, 1/3H), 3.13 (dd, $J=9$, $J'=8.5$ Hz, 2/3H), 3.05 (dd, $J=9$, $J'=8.5$ Hz, 1/3H), 2.47-2.40 (m, 1H), 2.35-2.22 (m, 2H), 2.15-1.85 (m, 2H), 1.45 (s, (3/9) 9H), 1.33 (s, (6/9) 9H).

c) Synthesis of compound 2d:

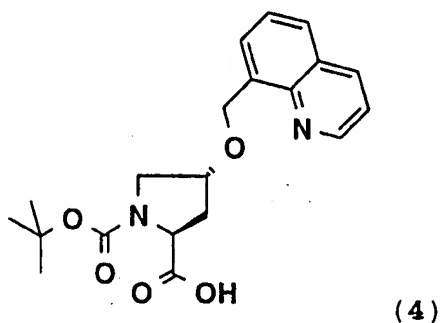
To a solution of compound **2c** (140 mg, 0.332 mmol) in ethanol (4 mL) was added 10% palladium on charcoal (30 mg). The mixture was stirred under an atmosphere of hydrogen for 2 h. The catalyst was removed by passing the mixture through a Millipore: Millex - HV 0.45 μm filter. The clear solution was concentrated to give the desired compound **2d** as a colorless oil (115 mg, quant. yield). ^1H NMR ($\text{DMSO}-d_6$) indicated the presence of two rotamers: δ 7.28-7.14 (m, 5H), 4.33 (br.s, 1H), 4.06-4.10, (m, 1H), 3.56-3.42 (m, 3H), 2.89-2.79 (m, 1H),), 2.53-2.49 (m, 1H, under $\text{DMSO}-d_6$), 2.24-2.10 (m, 1H), 2.03-1.93 (m, 1H), 1.87-1.75 (m, 1H), 1.62-1.45 (m, 2H), 1.38 (s, (3/9) 9H), 1.33 (s, (6/9) 9H).

Example 3

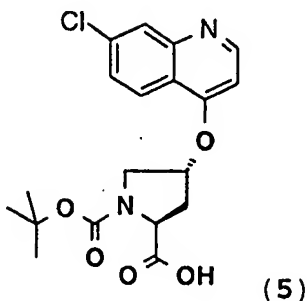
Synthesis of Boc-4(R)-(naphthalen-1-ylmethoxy) proline (3):



Commercially available Boc-4(*R*)-hydroxyproline (5.00 g, 21.6 mmol) was dissolved in THF (100 mL) and cooled to 0°C. Sodium hydride (60% dispersion in oil, 1.85 g, 45.4 mmol) was added portionwise over 10 minutes and the suspension was stirred at RT for 1 h. Then, 1-(bromomethyl)naphthalene (8.00 g, 36.2 mmol) (prepared as described in E.A. Dixon et al. Can. J. Chem., (1981), 59, 2629-2641) was added and the mixture was heated at reflux for 18 h. The mixture was poured into water (300 mL) and washed with hexane. The aqueous layer was acidified with 10% aqueous HCl and extracted twice with ethyl acetate. The organic layers were combined and washed with brine, dried (MgSO₄), filtered and concentrated. The residue was purified by flash chromatography (49:49:2 hexane: ethyl acetate: acetic acid) to give the title compound as a colorless oil (4.51 g, 56% yield). ¹H NMR (DMSO-d₆) indicated the presence of two rotamers: δ 8.05 (m, 1H), 7.94 (m, 1H), 7.29 (d, J=14 Hz, 1H), 7.55-7.45 (m, 4H), 4.96 (m, 2H), 4.26 (br. s, 1H), 4.12 (dd, J=J=8 Hz, 1H), 3.54-3.42 (m, 2H), 2.45-2.34 (m, 1H), 2.07-1.98 (m, 1H) 1.36 (s, (3/9) 9H), 1.34 (s, (6/9) 9H).

Example 4**Synthesis of Boc-4(R)-(8-quinoline-methyloxy) proline (4):**

5 Boc-4(R)-hydroxyproline (1.96 g, 8.5 mmol) in anhydrous THF (20 mL) was added to a suspension of NaH (1.4 g, 60% in oil, 34 mmol) in THF (100 mL). This mixture was stirred 30 min before bromomethyl-8-quinoline from Example 1 (2.54 g, 11.44 mmol) was
10 added in THF (30 mL). The reaction mixture was heated at 70°C (5 h) before the excess NaH was destroyed carefully with wet THF. The reaction was concentrated in vacuo and the resulting material was dissolved in EtOAc and H₂O. The basic aqueous phase was separated
15 and acidified with 10% aqueous HCl to pH ~5 before being extracted with EtOAc (150 mL). The organic phase was dried (MgSO₄), filtered and concentrated to give a brown oil. Purification by flash chromatography (eluent: 10% MeOH/CHCl₃) gave the
20 desired compound as a pale yellow solid (2.73 g, 86%). HPLC (97.5%); ¹H-NMR (DMSO-d₆) shows rotamer populations in a 6:4 ratio, δ 12-11.4 (bs, 1H), 8.92 (2 x d, J = 4.14 and 4.14 Hz, 1H), 8.38 (2 x d, J = 8.27 and 8.27 Hz, 1H), 7.91 (d, J = 7.94 Hz, 1H),
25 7.77 (d, J = 7.0 Hz, 1H), 7.63-7.54 (m, 2H), 5.14 (2 x s, 2H), 4.32-4.29 (m, 1H), 4.14-4.07 (m, 1H), 3.52-3.44 (m, 2H), 2.43-2.27 (m, 1H), 2.13-2.04 (m, 1H), 1.36 and 1.34 (2 x s, 9H).

Example 5**Preparation of Boc-4(R)-(7-chloroquinoline-4-oxo)proline (5):**

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Commercially available Boc-4(S)-hydroxyproline methyl ester (500 mg, 2.04 mmol) and 7-chloro-4-hydroxyquinoline (440 mg, 2.45 mmol) were placed in dry THF (10 mL) at 0°C. Triphenylphosphine (641 mg, 2.95 mmol) was added, followed by slow addition of DIAD (426 mg, 2.45 mmol). The mixture was stirred at RT for 20 h. The reaction mixture was then concentrated, taken up in ethyl acetate and extracted three times with HCl 1N. The aqueous phase was basified with Na₂CO₃ and extracted twice with ethyl acetate. The organic layers were combined, dried over MgSO₄, filtered and concentrated to give a yellow oil. The oil was purified by flash chromatography to give compound (5) methyl ester as a white solid, 498 mg, 58% yield.

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This methyl ester (400 mg, 0.986 mmol) was hydrolysed with 1M aqueous sodium hydroxide (1.7 mL, 1.7 mmol) in methanol (4 mL), at 0°C, for 3 h. The solution was concentrated to remove the methanol and neutralised with 1M aqueous HCl. The suspension was concentrated to dryness and taken up in methanol (20 mL), the salts were filtered off and the filtrate concentrated to give the desired compound (5) as a

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white solid, 387 mg, quant. yield.

¹H NMR (DMSO-d₆) (ca. 1:1 mixture of rotamers) δ 8.74 (d, J = 5 Hz, 1 H), 8.13-8.09 (m, 1 H), 7.99 and 7.98 (s, 1 H), 7.58 (d, J = 9 Hz, 1 H), 7.02 (d, J = 5 Hz, 1 H), 5.26-5.20 (m, 1 H), 4.10- 4.01 (m, 1 H), 3.81-3.72 (m, 1 H), 3.59 (dd, J = 12, 10 Hz, 1 H), 2.41-2.31 (m, 2 H), 1.34 and 1.31 (s, 9H).

Example 6

10 General procedure for coupling reactions done on solid support.

The synthesis was done on a parallel synthesizer model ACT396 from Advanced ChemTech® with the 96 well block. Typically, 24 peptides were synthesized in parallel using standard solid-phase techniques. The starting Fmoc-Nva-Wang resin and the 1-(Fmoc-amino)cyclopropane carboxylic acid-Wang resin were prepared by the DCC/DMAP coupling method (Atherton, E; Scheppard, R.C. *Solid Phase Peptide Synthesis, a Practical Approach*; IRL Press: Oxford 1989; pp 131-148). Other amino acid-Wang resins were obtained from commercial sources.

25 Each well was loaded with 100 mg of the starting resin (approximately 0.05 mmol). The resins were washed successively with 1.5 mL portions of NMP (1 X) and DMF (3 X). The Fmoc protecting group was removed by treatment with 1.5 mL of a 25% v/v solution of piperidine in DMF for 20 min. The resins were washed with 1.5 mL portions of DMF (4 X), MeOH (3 X) and DMF (3 X). The coupling was done in DMF (350 µL), using 30 400 µL (0.2 mmol) of a 0.5M solution of Fmoc-amino

acid/HOBt hydrate in DMF, 400 μ L (0.4 mmol) of a 0.5M solution of DIPEA in DMF and 400 μ L (0.2 mmol) of a 0.5M solution of TBTU in DMF. After shaking for 1 h, the wells were drained, the resins were washed with 1.5 mL of DMF and the coupling was repeated once more under the same conditions. The resins were then washed as described above and the cycle was repeated with the next amino acid.

- 10 The capping groups were introduced in two ways:
1. In the form of a carboxylic acid using the protocol described above (for example acetic acid) or,
 2. As an acylating agent such as an anhydride or an acid chloride. The following example illustrates the capping with succinic anhydride: After the Fmoc deprotection and subsequent washing protocol, DMF was added (350 μ L), followed by 400 μ L each of a DMF solution of succinic anhydride (0.5 M, 0.2 mmol) and DIPEA (1.0 M, 0.4 mmol). The resins were stirred for 2 h and a recoupling step was performed.

At the end of the synthesis the resin was washed with 1.5 mL portions of DCM (3 x), MeOH (3 x), DCM (3 x), and were dried under vacuum for 2 h.

The cleavage from the resin and concomitant side chain deprotection was effected by the addition of 1.5 mL of a mixture of TFA, H₂O, DTT and TIS (92.5: 2.5: 2.5: 2.5). After shaking for 2.5 h, the resin was filtered and washed with 1.5 mL of DCM. The filtrates were combined and concentrated by vacuum centrifugation.

Each compound was purified by preparative reversed phase HPLC using a C18 column (22 mm by 500 mm). The product-containing fractions were identified by MALDI-TOF mass spectrometry, combined and lyophilized.

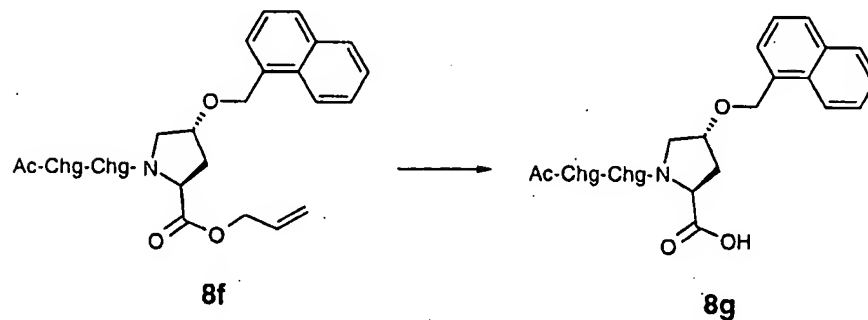
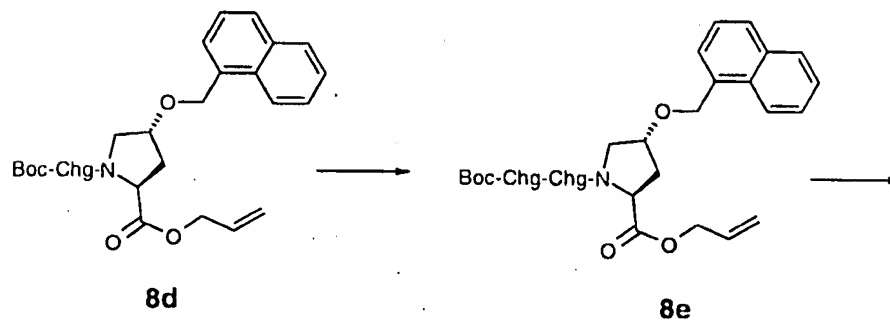
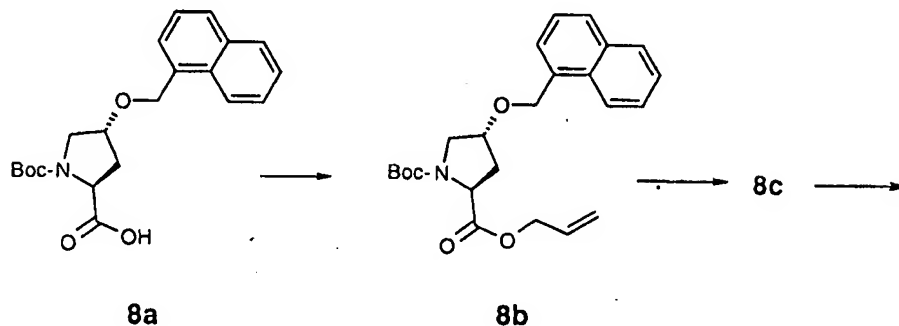
Example 7

General procedure for coupling reactions done in solution {See also R. Knorr et al., *Tetrahedron Letters*, (1989), 30, 1927.}

The reactants, i.e. a free amine (1 eq.) (or its hydrochloride salt) and the free carboxylic acid (1 eq.) were dissolved in CH_2Cl_2 , CH_3CN or DMF. Under a nitrogen atmosphere, four equivalents of N-methylmorpholine and 1.05 equivalents of the coupling agent were added to the stirred solution. After 20 min, one equivalent of the second reactant, i.e. a free carboxylic acid was added. (Practical and efficient coupling reagents for this purpose are (benzotriazol-1-yloxy)tris-(dimethylamino)phosphonium hexafluorophosphate (HOBt) or preferably 2-(1H-benzotriazol-1-yl)-N,N,N',N'-tetramethyluronium tetrafluoroborate (TBTU) or O-(7-azabenzotriazol-1-yl)-N,N,N',N'-tetramethyluronium tetrafluoroborate (HATU). The reaction is monitored by TLC. After completion of the reaction, the solvent was evaporated under reduced pressure. The residue was dissolved in EtOAc. The solution was washed successively with 10% aqueous citric acid, saturated aqueous NaHCO_3 and brine. The organic phase was dried (MgSO_4), filtered and concentrated under reduced pressure. When the residue was purified, it was done by flash chromatography as defined above.

Example 8

Synthesis of segment: Ac-Chg-Chg-Pro (4(R)-naphthalen-1-ylmethoxy)-OH (8g)



Compound **8a** (4.45g, 11.98 mmol) was dissolved in anhydrous CH_3CN (60 mL). DBU (2.2 mL, 14.38mmol) and allyl bromide (1.1 mL, 13.18 mmol) were added successively and the reaction mixture was stirred 24 h at RT. The mixture was concentrated, the resulting oil was diluted with EtOAc and water and successively washed with water (2x) and brine (1x). The EtOAc layer was dried (MgSO_4), filtered and evaporated to dryness. The yellow oil was purified by flash

chromatography (eluent:hexane:EtOAc;90:10 to 85:15) to provide the product **8b** as a yellow oil (2, 4.17g ; 85 % yield). MS (FAB) 412 MH⁺

¹H NMR (CDCl₃) , mixture of rotamers ca.1:2 , δ (d, J= 8Hz, 1H), 7.87 (d, J= 8Hz, 1H), 7.82 (d, J= 8Hz, 1H), 7.55-7.41 (m, 4H), 5.95-5.85 (m, 1H), 5.34-5.21 (m, 2H), 5.03-4.88 (m, 2H), 4.70-4.56 (m, 2H), 4.48 & 4.39 (t, J= 8, 15Hz, 1H), 4.28-4.23 (m, 1H), 3.81-3.55 (m, 2H), 2.46-2.36 (m, 1H), 2.13-2.05 (m, 1H), 1.44 & 1.41 (s, 9H).

Compound **8b** (2.08 g , 5.05 mmol) was treated for 30 min at RT with 4N HCl / dioxane. Evaporation to dryness provided the corresponding amine-HCl as an oil. The amine-HCl **8c** was dissolved in anhydrous DCM (25 mL) , NMM (2.2 mL, 20.22 mmol), Boc-Chg-OH · H₂O (1.53 g, 5.56 mmol) and TBTU (1.95 g, 6.07 mmol) were added successively. The reaction mixture was stirred at RT overnight, then, diluted with EtOAc and successively washed with 10% aqueous citric acid (2x), saturated aqueous NaHCO₃ (2x), water (2x), and brine (1x). The EtOAc layer was dried (MgSO₄), filtered and evaporated to dryness to provide the crude product **8d** as a yellowish-white foam (ca 2.78g, 100% yield). MS (FAB) 551.4 MH⁺. ¹H NMR (CDCl₃) δ 8.03(d, J= 8Hz, 1H), 7.86 (b d, J= 8.5Hz, 1H), 7.84 (d, J= 8Hz, 1H), 7.56-7.40 (m, 4H), 5.92-5.85 (m, 1H), 5.31 (dd, J= 1, 17Hz, 1H), 5.22 (dd, J= 1, 10Hz, 1H), 5.17 (d, J= 9Hz, 1H), 5.05 (d, J= 12Hz, 1H), 4.91 (d, J= 12Hz, 1H), 4.67-4.60 (m, 3H), 4.31-4.27 (m, 2H), 4.16 (b d, J= 11Hz, 1H), 3.71 (dd, J= 4, 11Hz, 1H), 2.47-2.41 (m, 1H), 2.08-1.99 (m, 1H), 1.85-1.63 (m, 5H), 1.44-1.40 (m, 1H), 1.36 (s, 9H), 1.28-1.00 (m, 5H).

The crude dipeptide **8d** (ca. 5.05 mmol) was treated with 4N HCl/dioxane (25 mL) as described for compound **8c**. The crude hydrochloride salt was coupled to Boc-Chg-OH · H₂O (1.53 g, 5.55 mmol) with NMM (2.22 mL, 20.22 mmol) and TBTU (1.95 g, 6.07 mmol) in DCM (25 mL) as described for compound **8d** to yield crude tripeptide as a yellow-oil foam. The crude material was purified by flash chromatography (eluent:hexane:EtOAc;80:20 to 75:25) to provide the tripeptide **8e** as a white foam (2.75 g; 79% yield over 2 steps). MS (FAB) 690.5 MH⁺. ¹H NMR (CDCl₃), mainly one rotamer, δ 8.06 (d, J= 8Hz, 1H), 7.87 (b d, J= 8.5Hz, 1H), 7.82 (d, J= 8Hz, 1H), 7.57-7.40 (m, 4H), 6.41 (d, J= 8.5Hz, 1H), 5.92-5.84 (m, 1H), 5.31 (dd, J= 1, 17Hz, 1H), 5.23 (dd, J= 1, 10.5Hz, 1H), 5.04 (d, J= 12Hz, 1H), 4.98 (b d, J= 7Hz, 1H), 4.93 (d, J=12Hz, 1H), 4.63-4.58 (m, 4H), 4.29-4.25 (m, 1H), 4.10-4.07 (m, 1H), 3.90-3.84 (m, 1H), 3.72 (dd, J= 4, 11Hz, 1H), 2.48-2.40 (m, 1H), 2.07-1.99 (m, 1H), 1.83-1.55 (m, 12H), 1.43 (s, 9H), 1.23-0.89 (m, 10H).

The tripeptide **8e** (2.75 g, 3.99 mmol) was treated with 4N HCl/dioxane (20 mL) as described for compound **8c**. The crude hydrochloride salt was dissolved in anhydrous DCM (20 mL). NMM (1.75 mL, 15.94 mmol) and acetic anhydride (752 μL, 7.97 mmol) were added successively. The reaction mixture was stirred overnight at RT, then diluted with EtOAc. The organic layer was washed successively with 10% aqueous citric acid (2x), saturated aqueous NaHCO₃ (2x), water (2x) and brine (1x), dried (MgSO₄), filtered, and evaporated to dryness to provide the crude tripeptide **8f** as a white foam (2.48 g, 98% yield).

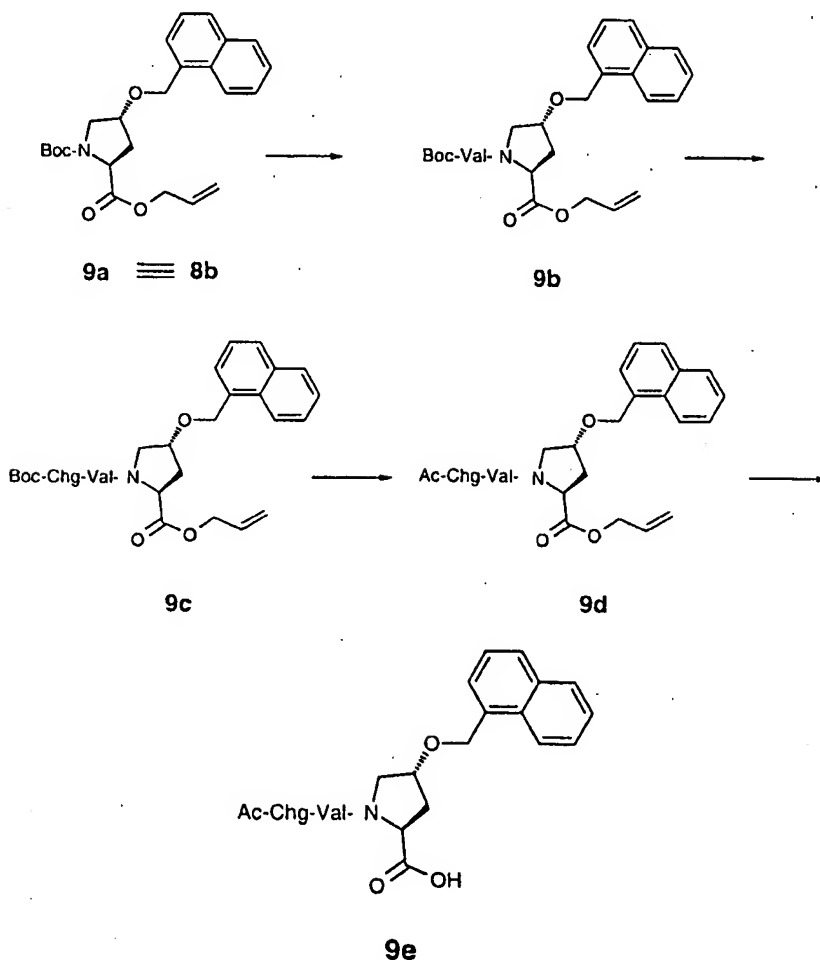
MS (FAB) 632.4 MH^+ . ^1H NMR (CDCl_3), mainly one rotamer, δ 8.06 (b d, $J = 8\text{Hz}$, 1H), 7.87 (b d, $J = 8\text{Hz}$, 1H), 7.83 (d, $J = 8\text{Hz}$, 1H), 7.58-7.40 (m, 4H), 6.36 (d, $J = 9\text{Hz}$, 1H), 6.01 (d, $J = 9\text{Hz}$, 1H), 5.94-5.83 (m, 1H), 5.34-5.28 (m, 1H), 5.25-5.21 (m, 1H), 5.05 (d, $J = 12\text{Hz}$, 1H), 4.94 (d, $J = 12\text{Hz}$, 1H), 4.64-4.57 (m, 4H), 4.30-4.23 (m, 2H), 4.12-4.08 (m, 1H), 3.73 (dd, $J = 4, 11\text{Hz}$, 1H), 2.49-2.42 (m, 1H), 2.08-2.01 (m, 1H), 1.99 (s, 3H), 1.85-1.53 (m, 11H), 1.25-0.88 (m, 11H).

The crude tripeptide **8f** (2.48 g, 3.93 mmol) was dissolved in an anhydrous mixture of CH_3CN : DCM (20 mL). Triphenylphosphine (53.5 mg, 0.200 mmol) and tetrakis(triphenylphosphine)-palladium (0) catalyst (117.9 mg, 0.102 mmol) were added successively, followed by pyrrolidine (353.9 μL , 4.24 mmol). The reaction mixture was stirred at RT for 18 h. Thereafter, the solvent was evaporated. The residue was dissolved in EtOAc and 10% aqueous citric acid, then, further washes twice more with 10% aqueous citric acid, water (2x), and brine (1x). The organic layer was dried (MgSO_4), filtered and evaporated. The crude product was triturated in Et_2O : DCM (85:15) to provide after filtration the tripeptide **8g** as a white solid (2.09 g, 90% yield). MS (FAB) 592.4 MH^+ 614.3 ($\text{M}+\text{Na}$) $^+$. ^1H NMR (CDCl_3), mainly one rotamer, δ 8.08 (d, $J = 8\text{Hz}$, 1H), 7.93 (b d, $J = 9\text{Hz}$, 1H), 7.88 (b d, $J = 8\text{Hz}$, 1H), 7.82 (d, $J = 8\text{Hz}$, 1H), 7.57-7.41 (m, 4H), 6.47 (d, $J = 8.5\text{Hz}$, 1H), 5.05 (d, $J = 12.5\text{Hz}$, 1H), 4.94 (d, $J = 12.5\text{Hz}$, 1H), 4.73 (t, $J = 9.5, 19\text{Hz}$, 1H), 4.44-4.35 (m, 2H), 4.26 (b s, 1H), 4.19 (d, $J = 11.5\text{Hz}$, 1H), 3.75 (dd, $J = 4, 11\text{Hz}$, 1H), 2.47 (b dd,

$J = 7.5, 13.5\text{Hz}$, 1H), 2.20-2.11 (m, 1H), 2.04 (s, 3H), 1.88-1.41 (m, 11H), 1.30-0.80 (11H).

Example 9

5 Synthesis of segment: Ac-Chg-Val-Pro(4(R)-naphthalen-1-ylmethoxy)-OH (9e)



Compound **9a** (2.89 g, 7.02 mmol) was treated with 4N HCl/dioxane (30 mL) as described for compound **8c**. The crude hydrochloride salt was coupled to Boc-Val-OH (1.53 g, 7.73 mmol) with NMM (3.1 mL, 28.09 mmol) and TBTU (2.71 g, 8.43 mmol) in DCM (35 mL) for 3.5 h as described for compound **3** to provide the crude dipeptide **9b** as an ivory oil-foam (ca. 3.60 g, 100% yield). MS (FAB) 509.3 MH^- 511.3 MH^+ 533.2 $(M+Na)^+$. 1H NMR (CDCl₃) δ 8.04 (b d, $J = 8\text{Hz}$, 1H),

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7.87 (b d, J= 7Hz, 1H), 7.82 (d, J= 8Hz, 1H), 7.56-7.40 (m, 4H), 5.93-5.85 (m, 1H), 5.34-5.28 (m, 1H), 5.24-5.19 (m, 2H), 5.04 (d, J= 12Hz, 1H), 4.92 (d, J= 12Hz, 1H), 4.67-4.60 (m, 3H), 4.31-4.26 (m, 2H),
5 4.11-4.09 (m, 1H), 3.72 (dd, J= 4, 11Hz, 1H), 2.48-2.41 (m, 1H), 2.07-1.99 (m, 1H), 1.44-1.36 (m, 1H), 1.37 (s, 9H), 1.01 (d, J= 7Hz, 3H), 0.93 (d, J= 7Hz, 3H).

10 The crude dipeptide **9b** (ca. 7.02 mmol) was treated with 4N HCl/dioxane (30 mL) as described for compound **7c**. The crude hydrochloride salt was coupled to Boc-Chg-OH · H₂O (2.13 g, 7.73 mmol) with NMM (3.1 mL, 28.09 mmol) and TBTU (2.71 g, 8.43 mmol) in CH₂Cl₂
15 (35 mL) as described for compound **3** to provide the crude tripeptide **9c** as an ivory foam (ca. 4.6 g, 100% yield). MS (FAB) 648.5 MH⁺ 672.4 (M+Na)⁺. ¹H NMR (CDCl₃) δ 8.06 (b d, J=8Hz, 1H), 7.87 (b d, J= 7.5 Hz, 1H), 7.82 (b d, J= 8Hz, 1H), 7.57-7.40 (m, 4H), 6.46 (b d, J= 8.5Hz, 1H), 5.94-5.84 (m, 1H),
20 5.31 (dd, J= 1, 17Hz, 1H), 5.23 (dd, J= 1, 10.5Hz, 1H), 5.03 (d, J= 12Hz, 1H), 5.00-4.97 (m, 1H), 4.93 (d, J=, 12Hz, 1H), 4.63-4.59 (m, 4H), 4.29-4.27 (m, 1H), 4.10-4.07 (m, 1H), 3.92-3.86 (m, 1H), 3.72 (dd, J= 5, 11Hz, 1H), 2.48-2.41 (m, 1H), 2.10-1.99 (m, 1H), 1.76-1.57 (m, 6H), 1.43 (s, 9H), 1.20-0.92 (m, 6H), 1.00 (d, J= 7Hz, 3H), 0.93 (d, J= 7Hz, 3H).
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The crude tripeptide **9c** (ca. 7.02 mmol) was treated
30 with 4N HCl/dioxane (30 mL) as described for compound **8c**. The crude hydrochloride salt was further treated with acetic anhydride (1.33 mL, 14.05 mmol) and NMM (3.1 mL, 28.09 mmol) in CH₂Cl₂ (35 mL) as described for compound **8f**. The crude product was flash

purified (eluent:hexane:EtOAc;30:70) to provide the acetylated protected tripeptide **9d** as a white foam (3.39 g, 81% yield over 3 steps). MS (FAB) 590.3 MH^- 592.4 MH^+ 614.4 $(M+Na)^+$

5 1H NMR ($CDCl_3$), mainly one rotamer, δ 8.06 (d, J = 8Hz, 1H), 7.88 (b d, J = 8Hz, 1H), 7.83 (d, J = 8Hz, 1H), 7.58-7.41 (m, 4H), 6.37 (d, J = 9Hz, 1H), 5.97 (d, J = 8.5 Hz, 1H), 5.94-5.84 (m, 1H), 5.31 (dd, J = 1, 17Hz, 1H), 5.24 (dd, J = 1, 10.5 Hz, 1H), 5.05 (d, J = 12Hz, 1H), 4.94 (d, J = 12Hz, 1H), 4.66-4.57 (m, 4H), 4.31-4.22 (m, 2H), 4.11-4.05 (m, 1H), 3.73 (dd, J = 4.5, 11Hz, 1H), 2.50-2.43 (m, 1H), 2.09-2.01 (m, 2H), 2.00 (s, 3H), 1.68-1.55 (m, 5H), 1.15-0.89 (m, 6H), 0.99 (d, J = 7Hz, 3H), 0.91 (d, J = 7Hz, 3H).

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The acetylated tripeptide **9d** (3.39 g, 5.73 mmol) was deprotected by tetrakis(triphenylphosphine)-palladium (0) catalyst (172.1 mg, 0.149 mmol) with triphenylphosphine (78.1 mg, 0.298 mmol) and

20 pyrrolidine (516 μ L, 6.19 mmol) in a 1:1 mixture of anhydrous CH_3CN : DCM (30 mL) as described for compound **8g**. The crude light yellow foam product was triturated in Et_2O : DCM (85:15) to provide after filtration the tripeptide **9e** as an off-white solid

25 (3.0 g; 95% yield). MS (FAB) 550.3 MH^-

1H NMR ($CDCl_3$) δ 8.08 (d, J = 8Hz, 1H), 8.04 (b d, J = 9Hz, 1H), 7.88 (b d, J = 7.5Hz, 1H), 7.82 (d, J = 8Hz, 1H), 7.58-7.37 (m, 5H), 5.05 (d, J = 12Hz, 1H), 4.94 (d, J = 12Hz, 1H), 4.61 (t, J = 9.5, 19.5Hz, 1H), 4.46-4.37 (m, 2H), 4.27 (b s, 1H), 4.17 (d, J = 11Hz, 1H), 3.74 (dd, J = 4, 11Hz, 1H), 2.49 (b dd, J = 7.5, 13Hz, 1H), 2.17-2.09 (m, 1H), 2.04 (s, 3H), 2.03-1.94 (m, 1H), 1.79 (b d, J = 12.5Hz, 1H), 1.62-1.43 (m, 5H),

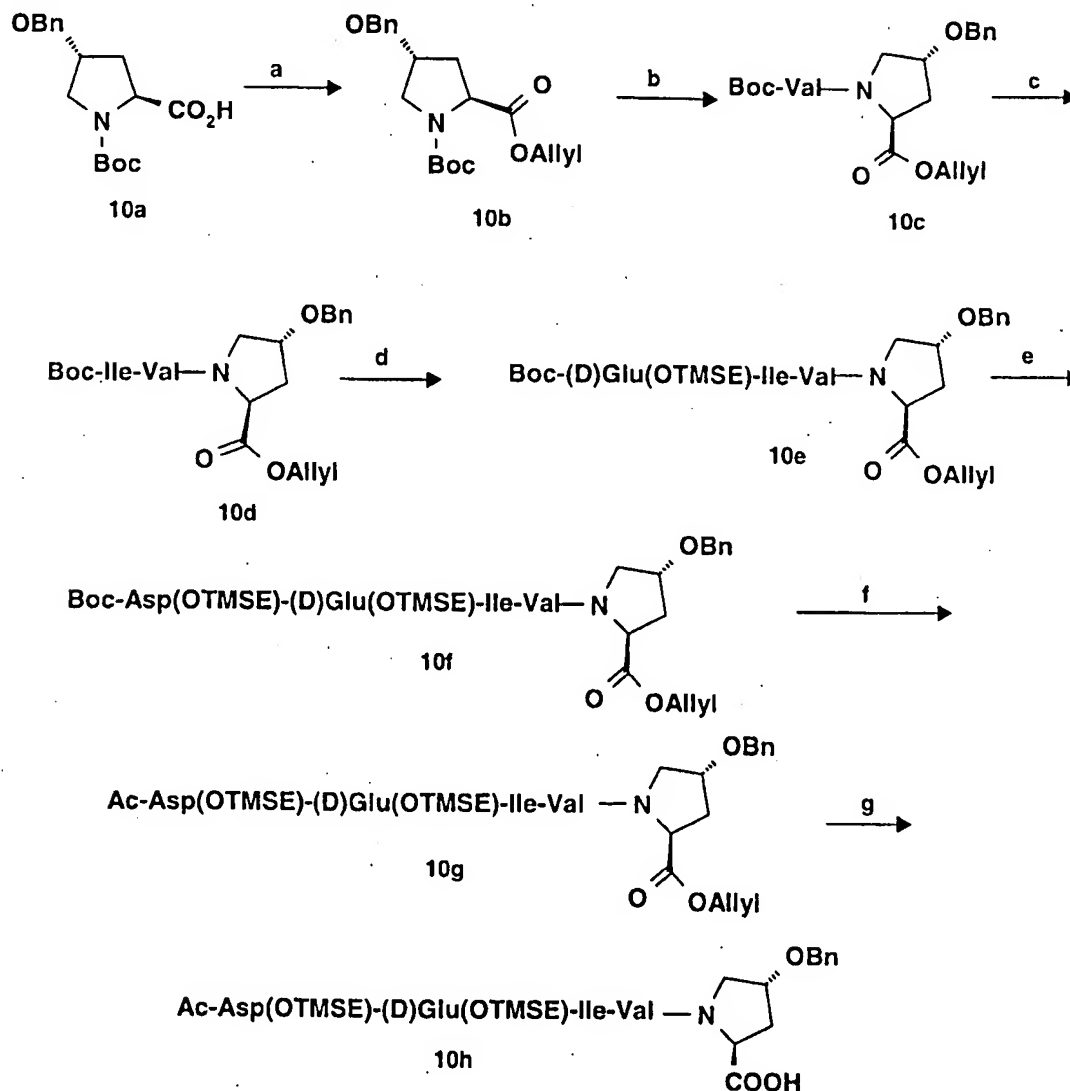
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1.08-0.85 (m, 5H), 1.00 (d, $J = 7\text{Hz}$, 3H), 0.90 (d, $J = 7\text{Hz}$, 3H).

Example 10**5 Synthesis of pentapeptide 10h:**

The synthesis was done as follows:

**10 a) Synthesis of compound 10b:**

To a solution of commercially available Boc-4(R)-benzyloxypyrrolidine (10a) (20.0 g, 62.2 mmol) in acetonitrile (250 mL) at 0°C were successively added DBU (10.3 mL, 68.87 mmol) and allyl bromide (6.0 mL, 69.3 mmol). The reaction mixture was stirred

overnight at RT, then the acetonitrile was evaporated and the residue dissolved in EtOAc. The mixture was sequentially washed with 10% aqueous citric acid (2x), water, saturated aqueous NaHCO₃, water (2x) and
5 brine. The EtOAc solution was dried (MgSO₄), filtered and concentrated to afford the desired ester **10b** (21.84 g, 60.42 mmol, 97% yield) as a colourless oil.

b) Synthesis of compound 10c:

10 Allyl ester **10b** (21.84 g, 60.42 mmol) was treated with a 4 N HCl solution in dioxane (453 mL, 1812.0 mmol) for 30 min before being concentrated *in vacuo*. The amine hydrochloride was subjected to the reaction conditions described in Example 3: The crude
15 hydrochloride salt was combined with Boc-Val-OH (13.13 g, 60.43 mmol), NMM (26.6 mL, 241.93 mmol), and TBTU (23.3 g, 72.56 mmol) in CH₂Cl₂ (300 mL). The reaction mixture was stirred for 16 h at RT and then concentrated *in vacuo*. The residue was dissolved in
20 EtOAc and washed sequentially with 10% aqueous citric acid (2x), water, saturated aqueous NaHCO₃ (2x), water (2x), and brine. The organic layer was dried (MgSO₄), filtered and concentrated to afford the crude dipeptide **10c** (30.23 g). MS (FAB) 461 (MH⁺).
25 ¹H-NMR (CDCl₃) δ 7.36-7.28 (m, 5H), 5.91-5.84 (m, 1H), 5.35-5.21 (m, 2H), 5.19 (bs, 1H), 4.66-4.62 (m, 3H), 4.56 (d, J = 11.8 Hz, 1H), 4.49 (d, J = 11.4 Hz, 1H), 4.28-4.24 (m, 2H), 4.04 (bd, J = 11.1 Hz, 1H), 3.70 (dd, J = 4.5, 11.1 Hz, 1H), 2.25-2.42 (m, 1H), 2.08-
30 1.98 (m, 1H), 1.45-1.40 (m, 1H), 1.41 (s, 9H), 1.01 (d, J = 6.7 Hz, 3H), 0.93 (d, J = 6.7 Hz, 3H).

c) Synthesis of compound 10d:

The crude dipeptide **10c** (ca. 60 mmol) was treated with a 4 N HCl in dioxane solution (453 mL). The crude hydrochloride salt was combined with Boc-Ile-OH (14.0 g, 60.5 mmol), TBTU (23.3g, 72.6 mmol) and NMM (26.6 mL, 241.9 mmol, 4.0 eq.) in CH₂Cl₂ (300 mL) as described for compound **10c** to afford the crude tripeptide **10d**. Purification by flash chromatography (using a mixture of 30% EtOAc in hexane) gave the desired compound **10d** (25.61 g, 44.64 mmol, 72% yield from compound **10a**). MS (FAB) 574 (MH⁺); ¹H-NMR (CDCl₃) δ 7.37-7.28 (m, 5H), 6.44 (d, J = 8.6 Hz, 1H), 5.95-5.84 (m, 1H), 5.35-5.23 (m, 2H), 5.99 (d, J = 8.4 Hz, 1H), 4.65-4.47 (m, 3H), 4.56 (d, J = 11.8 Hz, 1H), 4.49 (d, J = 12.1 Hz, 1H), 4.27-4.21 (m, 1H), 4.03 (bd, J = 10.8 Hz, 1H), 3.97-3.88 (m, 1H), 3.71 (dd, J = 4.1 Hz, J = 10.8 Hz, 1H), 2.49-2.41 (m, 1H), 2.12-2.00 (m, 2H), 1.85-1.74 (m, 1H), 1.55-1.40 (m, 2H), 1.43 (s, 9H), 1.16-1.04 (m, 1H), 1.00 (d, J = 6.7 Hz, 3H), 0.93 (d, J = 6.7 Hz, 3H), 0.89-0.82 (m, 6H).

d) Synthesis of compound 10e:

Tripeptide **10d** (25.60 g; 44.62 mmol) was treated with a 4 N HCl in dioxane solution (30 min) before being concentrated in vacuo to give 22.64 g of the hydrochloride salt. The hydrochloride salt (14.97 g, 29.35 mmol) was combined with Boc-(D)Glu(OTMSE)-OH (10.2 g, 29.35 mmol), TBTU (11.30 g, 35.23 mmol) and NMM (11.30 g, 35.23 mmol) in CH₂Cl₂ (150 mL) as described for compound **10c**. Compound **10e** was obtained as an off-white foam (23.6 g). MS (FAB) 803.5 (MH⁺); ¹H-NMR (CDCl₃) δ 7.34-7.28 (m, 5H), 6.74 (d, J = 8.26 Hz, 1H), 6.49 (d, J = 8.90 Hz, 1H), 5.93-5.86 (m, 1H), 5.44-5.36 (m, 1H), 5.35-5.22 (m,

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2H), 4.64-4.48 (m, 6H), 4.27-4.15 (m, 4H), 4.02 (d, J = 11.13 Hz, 1H), 3.71 (dd, J = 11.13, 4.45 Hz, 2H), 2.49-2.41 (m, 2H), 2.40-2.34 (m, 1H), 2.18-2.00 (m, 3H), 1.96-1.71 (m, 2H), 1.50-1.40 (m, 1H), 1.43 (s, 9H), 1.15-1.04 (m, 1H), 1.02-0.95 (m, 1H), 0.97 (d, J = 8.27 Hz, 3H), 0.90 (d, J = 7.00 Hz, 3H), 0.87-0.82 (m, 1H), 0.84 (d, J = 6.67 Hz, 6H), 0.04 (s, 9H).

e) Synthesis of compound 10f:

10 The crude tetrapeptide **10e** (ca. 28.91 mmol) was treated with a 4 N HCl in dioxane solution for 30 min (150 mL). The crude hydrochloride salt was combined with Boc-Asp(OTMSE)-OH (10.15 g, 30.44 mmol), NMM (12.7 mL, 115.6 mmol), and TBTU (11.14 g, 34.70 mmol) 15 in CH₂Cl₂ (150 mL) as described for compound **10c**. Pentapeptide **10f** was obtained as a light yellow foam (ca. 29.5 g). MS (FAB) 1018 (MH⁺); ¹H-NMR (CDCl₃) δ 7.36-7.28 (m, 6H), 6.78 (d, J = 8.90 Hz, 1H), 6.72 (d, J = 8.58 Hz, 1H), 6.22 (d, J = 7.94 Hz, 1H), 20 5.93-5.83 (m, 1H), 5.33-5.21 (m, 2H), 4.62-4.57 (m, 6H), 4.49-4.36 (m, 2H), 4.30 (dd, J = 8.90, 6.35 Hz, 1H), 4.23-4.14 (m, 5H), 3.72 (dd, J = 11.13, 4.77 Hz, 2H), 2.89 (dd, J = 16.85, 6.36 Hz, 1H), 2.79 (dd, J = 16.85, 6.36 Hz, 1H), 2.48-2.27 (m, 3H), 2.21-1.94 (m, 25 5H), 1.46-1.42 (m, 1H), 1.45 (s, 9H), 1.17-1.07 (m, 1H), 1.00-0.86 (m, 4H), 0.99 (d, J = 6.68 Hz, 3H), 0.93 (d, J = 6.68 Hz, 3H), 0.90 (d, J = 6.67 Hz, 6H), 0.04 (s, 9H), 0.02 (s, 9H).

30 **f) Synthesis of compound 10g:**

The Boc-pentapeptide **10f** (ca. 28.91 mmol) was treated with a 4 N HCl in dioxane solution (150 mL) for 30 min before being concentrated in vacuo. The crude hydrochloride salt was dissolved in anhydrous DMF

(150 mL) followed by the successive addition of pyridine (51.4 mL, 636.2 mmol) and acetic anhydride (51.6 mL, 546.5 mmol). The reaction mixture was stirred overnight at RT then poured into brine and extracted with EtOAc (3x). The combined organic extracts were washed sequentially with 10% aqueous citric acid (2x), saturated NaHCO₃ (2x), water (2x), and brine (1x). The organic layer was dried (MgSO₄), filtered and evaporated to dryness. The oil/foam residue was purified by flash chromatography (eluent, hexane:EtOAc; 4:6) to provide the acetylated pentapeptide **10g** as a white amorphous solid (17.56 g, 63% yield from compound **10d**). MS (FAB) 960.7 (MH⁺) 982.9 (MNa⁺); ¹H-NMR (CDCl₃) δ 7.72 (d, J = 9.22 Hz, 1H), 7.35-7.28 (m, 6H), 7.12 (d, J = 9.54 Hz, 1H), 6.63 (d, J = 8.26 Hz, 1H), 5.91-5.81 (m, 1H), 5.32-5.22 (m, 2H), 5.20-4.96 (m, 1H), 4.68-4.54 (m, 5H), 4.49-4.36 (m, 3H), 4.28-4.20 (m, 3H), 4.19-4.12 (m, 2H), 3.74 (dd, J = 11.76, 5.40 Hz, 2H), 2.93 (dd, J = 17.48, 4.45 Hz, 1H), 2.81 (dd, J = 17.49, 6.36 Hz, 1H), 2.47-2.39 (m, 2H), 2.33-2.24 (m, 1H), 2.14-1.95 (m, 5H), 2.03 (s, 3H), 1.52-1.42 (m, 1H), 1.17-1.07 (m, 1H), 1.02-0.88 (m, 16H), 0.04 (s, 9H), 0.03 (s, 9H).

25

g) Synthesis of compound 10h:

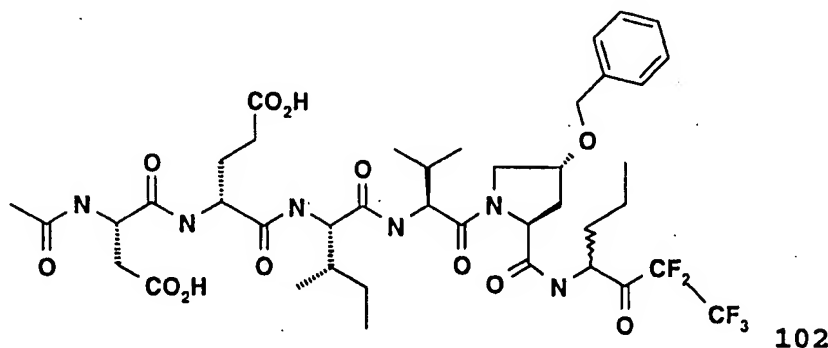
The pentapeptide **10g** (16.01 g, 16.67 mmol) was suspended in anhydrous acetonitrile (100 mL) and treated successively with triphenylphosphine (227.4 mg, 0.87 mmol) and tetrakis(triphenylphosphine)-palladium (0) catalyst (501 mg, 0.433 mmol) followed by pyrrolidine (1.5 mL, 18.01 mmol). The reaction mixture was mechanically stirred for 4 h at RT and then concentrated in vacuo. The residue was dissolved

30

in EtOAc and washed sequentially with 10% aqueous citric acid (3x), water (3x), and brine (1x). The organic phase was dried (MgSO_4), filtered and evaporated to dryness. The crude product was purified by flash chromatography (eluent, 1 % HOAc, 2.3 % MeOH in CHCl_3) to provide the pentapeptide **10h** as a white amorphous solid (11.45 g, 75% yield). MS (FAB) 920 (MH^+), 942 (MNa^+), 958.6 ($\text{M}+\text{K}$); $^1\text{H-NMR}$ (CDCl_3) δ 7.53(d, $J = 8.90$ Hz, 1H), 7.40 (d, $J = 7.32$ Hz, 1H), 7.35-7.28 (m, 5H), 7.22-7.17 (m, 1H), 6.83 (d, $J = 7.31$ Hz, 1H) 5.00-4.94 (m, 1H), 4.64-4.61 (m, 2H), 4.53-4.44 (m, 3H), 4.35 (dd, $J = 8.26, 6.04$ Hz, 1H), 4.28-4.24 (m, 1H), 4.18-4.09 (m, 5H), 3.72 (dd, $J = 10.81, 4.14$ Hz, 1H), 2.87-2.84 (m, 2H), 2.47-2.41 (m, 2H), 2.34-2.24 (m, 1H), 2.16-1.97 (m, 5H), 2.06 (s, 3H), 1.52-1.42 (m, 1H), 1.17-1.08 (m, 1H), 1.01-0.84 (m, 16H), 0.04 (s, 9H), 0.03 (s, 9H).

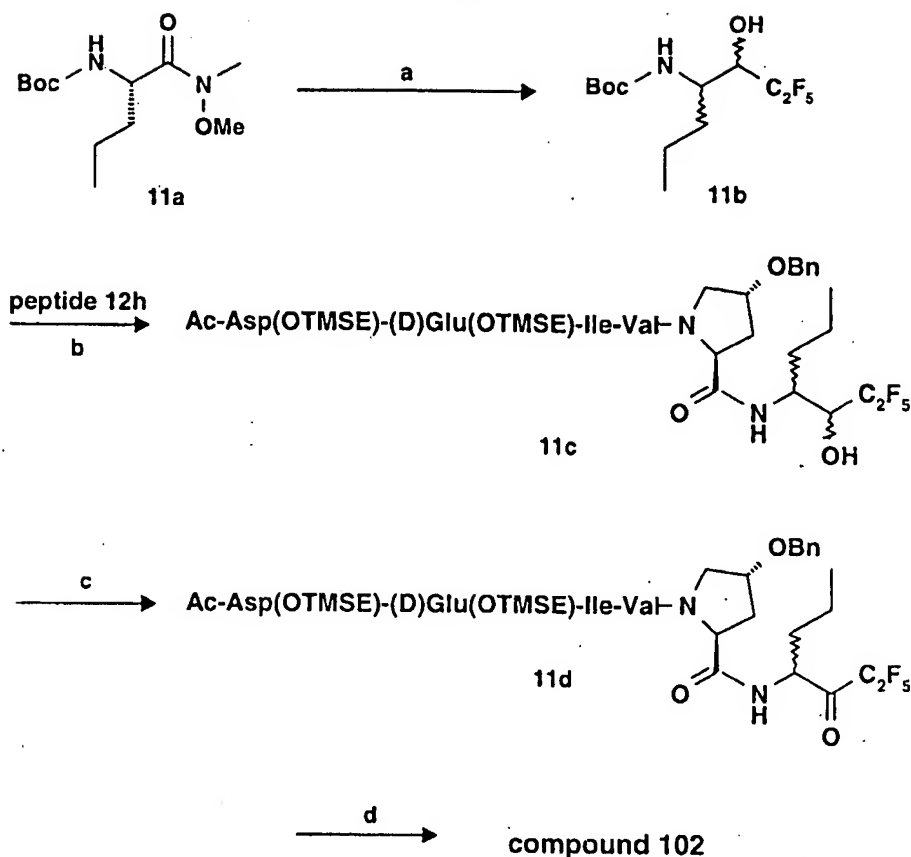
Example 11

20 Synthesis of compound 102 (Table 1)



The synthesis was done as shown below:

73

**a) Synthesis of compound 11b:**

A cold (-78°C) solution of commercially available pentafluoroethyl iodide (6.4 g, 26.02 mmol) in dry ether (16.7 mL) was slowly cannulated (10 min) into a -78°C solution of MeLi.LiBr in ether (14.0 mL of a 1.5 M solution in ether, 21.0 mmol). After an additional 10 min at -78°C Weinreb amide **11a** (prepared from commercially available Boc-Nva-OH according to the procedure of Castro, B. et al. Synthesis, (1983), 676-678.) (2.02 g, 7.76 mmol) in ether (5 mL) was added. The reaction mixture was stirred for 1 hr at -78°C and then at -40°C for 15 min. A saturated aqueous solution of NH_4Cl was then added. The mixture was extracted 3 times with EtOAc and the combined organic extract was washed with

brine. The EtOAc solution was finally dried over MgSO_4 , filtered and concentrated.

The crude pentafluoroethyl ketone was dissolved in a mixture of THF (38 mL) and MeOH (9.5 mL) and the resulting solution was cooled to 0°C for the addition of sodium borohydride (323 mg, 8.54 mmol, 1.1 eq.). After 15 min, ether was added and the mixture was washed with a 10% aqueous citric acid solution. The aqueous layer was extracted 3 times with ether and the combined organic layer was successively washed with a saturated aqueous NaHCO_3 solution (2X), water and brine. The ether solution was dried (Na_2SO_4), filtered and concentrated. The residue was flash chromatographed using a mixture of EtOAc (15%) and hexane (85%) to afford the desired alcohols (1.30 g, 4.05 mmol, 52 % yield from the amide **11a**). ^1H NMR (CDCl_3) (mixture of 2 diastereomers in a 1:1 ratio) δ 4.75 (bs, 1/2H), 4.54 (bs, 1/2H), 4.21-4.13 (m, 1H), 3.92 (dd, $J = 6.0$ Hz, $J' = 14.6$ Hz, 1H), 1.65-1.29 (m, 4H), 1.45 (m, 9H), 0.98-0.93 (m, 3H).

b) Synthesis of compound 11c:

Compound **11b** (96 mg, 0.30 mmol) was treated with a 4 N HCl solution in dioxane for 30 min before being concentrated in vacuo. The crude hydrochloride salt was dissolved in dry DMF (1 mL). The pentapeptide **10h** (204 mg, 0.22 mmol), NMM (0.1 mL, 0.91 mmol, 4 eq.) and TBTU (85 mg, 0.26 mmol, 1.2 eq.) were then successively added. The reaction mixture was stirred overnight at RT, then poured into brine and extracted 3 times with EtOAc. The combined organic extract was successively washed with a 10% aqueous citric acid solution (2x), water, saturated aqueous NaHCO_3 solution, water (2x) and brine. The EtOAc

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solution was dried (MgSO_4), filtered and concentrated. The residue was purified by flash chromatography using a mixture of EtOAc (75 to 80 %) and hexane (25 to 20%) to afford the desired compound **11c** (154 mg, 0.137 mmol, 62 % yield). MS (FAB) 1123 (MH^+).

c) Synthesis of compound 11d:

To the mixture of alcohols **11c** (52 mg, 0.047 mmol) in a solution of DMSO (0.5 mL) and toluene (0.5 mL) were successively added dichloroacetic acid (11.5 mL, 0.139 mmol) and EDAC (89 mg, 0.464 mmol). The reaction mixture was stirred overnight at RT, poured into brine (30 mL) and extracted with EtOAc (3x 15 mL). The combined organic extract was successively washed with saturated aqueous NaHCO_3 , water (2x) and brine. The EtOAc solution was dried (MgSO_4), filtered and concentrated. The residue was purified by flash chromatography using a mixture of EtOAc (75 to 80%) and hexane (25 to 20%) to afford the desired ketone **11d** (37 mg, 0.032 mmol, 70% yield). MS (FAB) 1121 (MH^+).

d) Synthesis of compound 102:

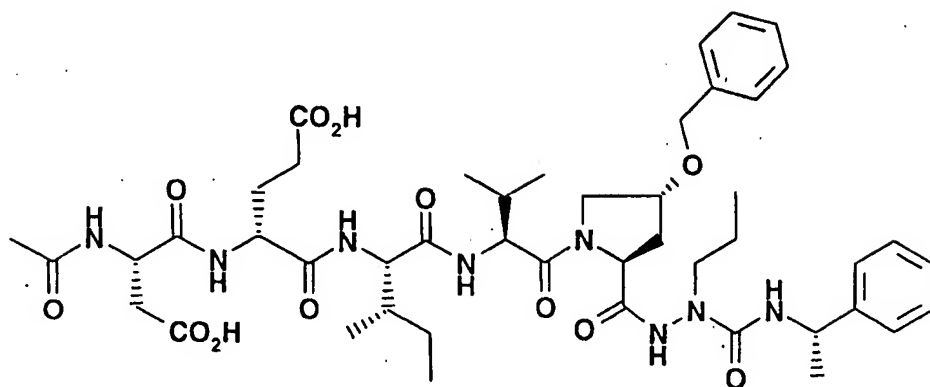
The mixture of ketone **11d** (37 mg, 0.032 mmol) was dissolved in TFA (1 mL) and the resulting solution was stirred for 1 h at RT. After removal of the volatiles under vacuum, the desired peptide was obtained (29 mg, 0.031 mmol, 97%). MS (FAB) 921 (MH^+), 943 (MNa^+). ^1H NMR (CDCl_3) (mixture of 2 diastereomers in a 1.35:1 ratio) δ 8.14 (d, J = 7.6 Hz, 1H), 8.07-8.02 (m, 2H), 7.80-7.78 (m, 1H), 7.35-7.26 (m, 5H), 4.77-4.56 (m, 1H), 4.56-4.38 (m, 5H), 4.34-4.09 (m, 5H), 2.68-2.59 (m, 2H), 2.26-2.15 (m,

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3H), 2.02-1.82 (m, 3H), 1.82 (s, 3H), 1.78-1.28 (m, 6H), 1.07-0.95 (m, 1H), 0.92-0.80 (m, 10H), 0.77-0.68 (m, 8H).

5 **Example 12**

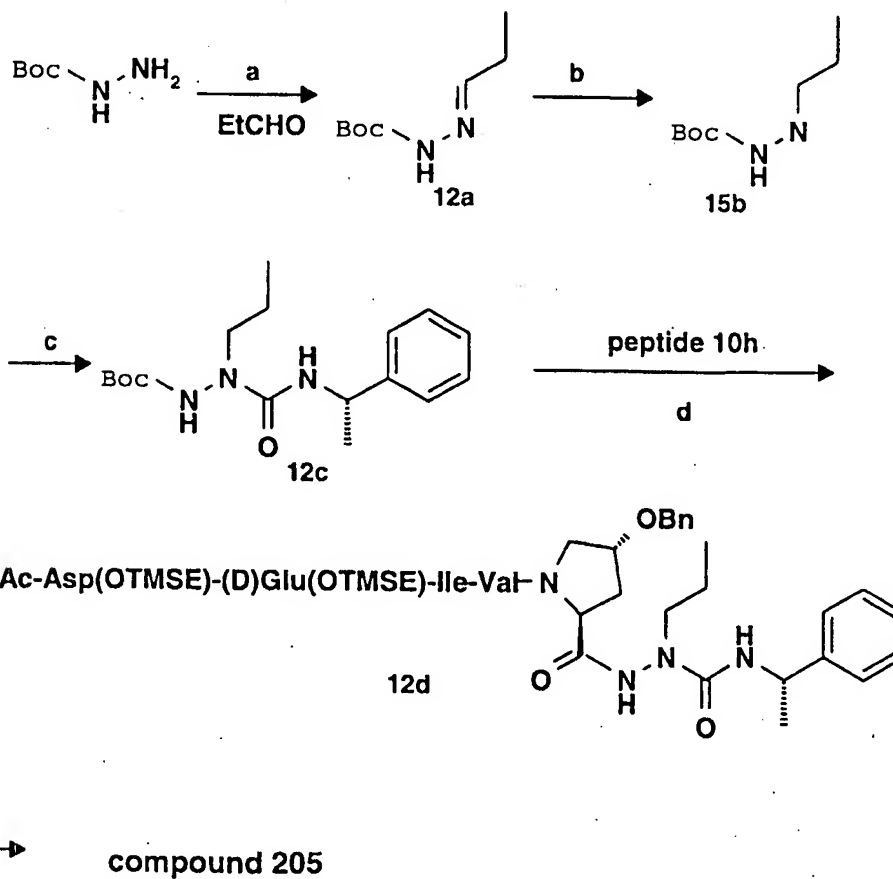
Synthesis of compound 205 (Table 2).



205

Compound 205 was prepared according to the following scheme:

10



a) Synthesis of compound 12a:

To a solution of Boc-hydrazine (3.0 g, 22.6 mmol) in toluene (42 mL) was added propionaldehyde (1.8 mL, 24.9 mmol). The solution was heated to 50°C for 1 h and then stirred at RT for 24 h. The mixture was concentrated to give **12a** as a white solid (3.70 g, 95%) which was homogeneous by analytical HPLC (97.5%). MS (FAB) 173.1 (MH⁺); ¹H-NMR (DMSO-d₆) δ 10.33 (bs, 1H), 7.28 (bs, 1H), 2.19-2.09 (m, 2H), 1.42 and 1.41 (2 x s, 9H), 0.97 (dt, J = 7.6, 1.6 Hz, 3H).

b) Synthesis of compound 12b:

To the hydrazone **12a** (3.7 g, 21.48 mmol) in THF (80 mL) at -78°C was added DIBAL (31 mL, 47.25 mmol) as a 1.5 M solution in toluene. The reaction was maintained at -78°C for 2 h and then -40°C for 2 h. Rochelle's salt (aqueous potassium sodium tartrate) solution was added and the reaction mixture stirred at RT overnight. The organic phase was separated and the aqueous phase extracted with Et₂O (2 x 75 mL). The combined organic extracts were washed with brine, dried (Na₂SO₄), filtered and concentrated in vacuo. Purification by flash chromatography on silica gel gave **12b** as a colourless oil (3.4 g, 91%). MS (CI-NH₃) 175.2 (MH⁺); ¹H-NMR (DMSO-d₆) δ 8.10 (bs, 1H), 4.25 (bs, 1H), 2.6 (t, J = 7.0 Hz, 2H), 1.45-1.29 (m, 2H), 1.38 (s, 9H), 0.85 (t, J = 7.6 Hz, 3H).

c) Synthesis of compound 12c:

The hydrazine **12b** (0.20 g, 1.15 mmol) was combined with (S)-(-)-1-phenylethylisocyanate (0.162 g, 1.15 mmol) in CH₂Cl₂ (2.4 mL) with DIPEA (0.44 mL, 2.52 mmol) and stirred at 0°C for 1 h, and then at RT for

3 h. The mixture was concentrated in vacuo to give a white solid which was purified by flash chromatography to give compound **12c** (0.25 g, 68%). MS (FAB) 322.3 (MH^+); 1H -NMR (DMSO- d_6) δ 8.90 and 8.48 (2 x bs, 1H), 7.35-7.23 (m, 5H), 6.84 (t, J = 7.0 Hz, 1H), 6.50 (bs, 1H), 4.79 (t, J = 7.3 Hz, 1H), 1.41 (s, 9H), 1.36 (d, J = 7.0 Hz, 6H), 0.81 (t, J = 7.3 Hz, 3H).

10 **d) Synthesis of compound 12d:**

Compound **12c** (77 mg, 0.24 mmol) was treated with 4 N HCl/dioxane (1.2 mL) for 20 min before being concentrated in vacuo. The hydrochloride salt was combined with the pentapeptide **10h** (0.20 g, 0.22 mmol), TBTU (85 mg, 0.26 mmol), and diisopropylethylamine (0.13 mL, 0.73 mmol) in DMF (2.5 mL) at RT for 16 h. The reaction mixture was concentrated and the residue dissolved in EtOAc and washed sequentially with saturated aqueous $NaHCO_3$, 10% aqueous HCl, and brine before being dried ($MgSO_4$), filtered, and concentrated in vacuo. Purification by flash chromatography gave **12d** as a white solid (80 mg, 33%).

25 **e) Synthesis of compound 205:**

The protected peptide **12d** (75 mg, 0.067 mmol) was treated with neat TFA (1.5 mL) for 1.5 h before being concentrated in vacuo. Purification by preparative HPLC gave **205** as a white solid (17 mg, 27%). HPLC (98%); MS (FAB) 923.6 (MH^+); HRMS calcd for $C_{46}H_{66}N_8O_{12}$ (MH^+) 923.48785, found: 923.49097. 1H -NMR (DMSO- d_6) δ 12.5-11.9 (bs, 2H), 10.31 (bs, 1H), 8.26 (d, J = 7.95 Hz, 1H), 8.14 (d, J = 7.6 Hz, 1H), 7.98 (d, J = 8.26 Hz, 1H), 7.78 (d, J = 8.58 Hz, 1H), 7.42-7.26 (m,

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10H), 7.20 (t, J = 7.0 Hz, 1H), 6.86 (bd, 1H), 4.85-4.77 (m, 1H), 4.55 (d, J = 11.4 Hz, 1H), 4.50-4.40 (m, 1H), 4.46 (d, J = 11.8 Hz, 1H), 4.36-4.20 (m, 6H), 3.75-3.68 (m, 1H), 3.48-3.34 (bs, 1H), 3.18-3.07 (bs, 1H), 2.62 (dd, J = 16.5, 5.7 Hz, 1H), 2.44 (dd, J = 16.5, 5.7 Hz, 1H), 2.30-2.22 (m, 1H), 2.17 (t, J = 7.95 Hz, 2H), 2.06-1.84 (m, 2H), 1.81 (s, 3H), 1.80-1.59 (m, 2H), 1.42-1.30 (m, 6H), 1.06-0.98 (m, 1H), 0.88 (t, J = 7.0 Hz, 6H), 0.78 (t, J = 7.3 Hz, 3H), 0.71 (t, J = 7.0 Hz, 6H).

Example 13

Synthesis of compound 231

Compound 231 was prepared according to the procedure for compound 205 except that the isocyanate was replaced by the corresponding isocyanate prepared from piperonylamine in the following manner. To a solution of phosgene in toluene (0.2 mL, 0.38 mmol, 4 equiv.) and THF (0.7 mL) at 0°C was added piperonylamine (12 µL, 0.095 mmol) in THF (0.7 mL) containing diisopropylethylamine (53 µL, 0.30 mmol) dropwise over a period of 15 min. The mixture was stirred at 0°C for 30 min before being concentrated. The generated isocyanate was coupled as described for compound 12c. The Boc group was removed (4 N HCl/dioxane) and the hydrochloride salt of fragment P1/P1' was coupled in the usual fashion with HATU, diisopropylethylamine and the pentapeptide 10h (0.10 g, 0.095 mmol) in DMF. The reaction mixture was stirred at 0°C for 1 h and then at RT for 16 h. The reaction mixture was concentrated and the residue dissolved in EtOAc and washed sequentially with saturated aqueous NaHCO₃, 10% aqueous HCl, and brine before being dried (MgSO₄), filtered and concentrated

in vacuo. Purification by flash chromatography gave the desired protected peptide (67 mg, 62.5%).

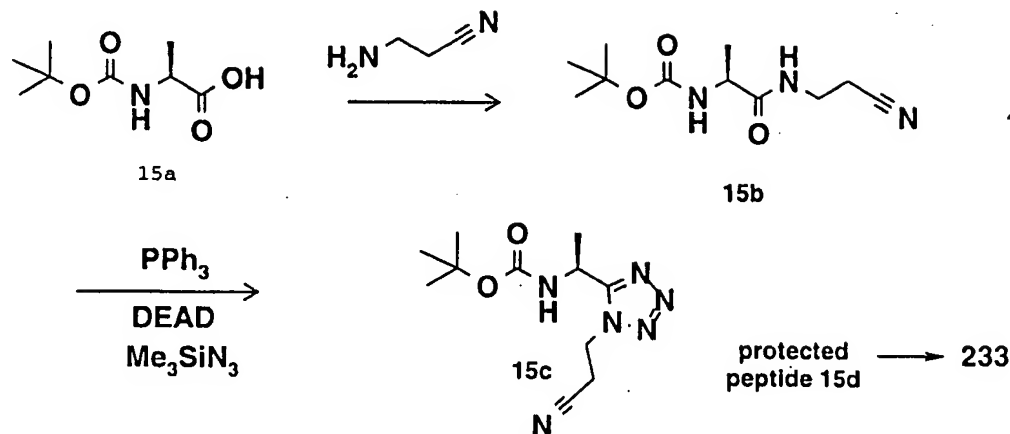
The protected peptide (63 mg, 0.056 mmol) was treated
5 as for the synthesis of compound **12d** to give after
purification by preparative HPLC compound **231** as a
white solid (17 mg, 32%). HPLC (100%); MS (FAB)
953.05 (MH⁺); HRMS calcd for C₄₆H₆₄N₈O₁₄ (MH⁺)
953.46204, found: 953.46680. ¹H-NMR (DMSO-d₆) δ 10.35
10 (bs, 1H), 8.17 (d, J = 8.6 Hz, 1H), 8.15 (d, J = 7.95
Hz, 1H), 7.98 (d, J = 7.95 Hz, 1H), 7.76 (d, J = 8.6
Hz, 1H), 7.40-7.25 (m, 5H), 7.23-7.13 (bs, 1H), 6.82
(s, 1H), 6.79 (d, J = 7.6 Hz, 1H), 6.72 (d, J = 7.6
Hz, 1H), 5.95 (s, 2H), 4.57-4.43 (m, 3H), 4.34-4.18
15 (m, 6H), 4.13-4.08 (m, 2H), 3.70 (d, J = 3.8 Hz, 1H),
3.67 (d, J = 3.8 Hz, 1H), 2.68-2.58 (m, 2H), 2.48-
2.42 (m, 1H), 2.34-2.24 (m, 2H), 2.2-2.13 (m, 2H),
2.05-1.94 (m, 1H), 1.94-1.82 (m, 1H), 1.81 (s, 3H),
1.75-1.61 (m, 2H), 1.45-1.30 (m, 3H), 1.03-0.94 (m,
20 1H), 0.87-0.75 (m, 9H), 0.74-0.67 (m, 6H).

Example 14

Synthesis of compound **232**

Compound **12b** was coupled to the appropriate
25 carboxylic acid (from Maybridge) using TBTU and
diisopropylethylamine in DMF in the usual fashion.
The Boc group from the P1/P1' fragment was removed (4
N HCl/dioxane, 30 min) and the corresponding
hydrochloride salt (0.104 mmol) coupled to peptide
30 **10h** (0.10 g, 0.095 mmol) in the usual fashion with
HATU (39.5 mg, 0.104 mmol) and diisopropylethylamine
(0.07 mL, 0.4 mmol) in DMF (0.95 mL) for 16 h. The
mixture was concentrated and the residue extracted
into EtOAc and washed with saturated aqueous NaHCO₃,

10% aqueous HCl and brine before being dried
(Na₂SO₄), filtered and concentrated *in vacuo* to give
the protected peptide (110 mg, 100%). Final
deprotection of this peptide was accomplished by
5 saponification. The protected peptide (0.105 mg, 0.09
mmol) was dissolved in THF (1.3 mL), MeOH (0.7 mL)
and H₂O (0.7 mL) before being treated with aqueous
NaOH (0.18 mL of a 2 N solution, 0.36 mmol). The
mixture was stirred for 3.5 h before being
10 concentrated *in vacuo*. The crude residue was purified
by preparative HPLC to give compound **232** as a white
solid (33 mg, 36%). HPLC (97%); MS (FAB) 977.4 (MH⁺),
999.4 (MNa⁺); HRMS calcd for C₄₇H₆₄N₁₀O₁₃ (MH⁺)
977.47327, found: 97747620. ¹H-NMR (DMSO-d₆) δ 10.61
15 (bs, 1H), 8.75 (d, J = 4.7 Hz, 1H), 8.14 (d, J = 8.6
Hz, 1H), 8.06 (d, J = 7.6 Hz, 1H), 8.02-7.90 (m, 3H),
7.87 (d, J = 8.6 Hz, 1H), 7.60-7.56 (m, 1H), 7.35-
7.26 (m, 5H), 4.57-4.43 (m, 4H), 4.42-4.34 (m, 2H),
4.33-4.25 (m, 2H), 4.25-4.17 (m, 2H), 3.70 (dd, J =
20 10.5, 10.5 Hz, 1H), 3.21-3.10 (m, 2H), 2.96-2.80 (m,
1H), 2.69-2.60 (m, 2H), 2.48-2.41 (m, 1H), 2.35-2.25
(m, 1H), 2.22-2.15 (m, 2H), 2.05-1.90 (m, 2H), 1.88-
1.81 (m, 1H), 1.80 (s, 3H), 1.77-1.61 (m, 2H), 1.53-
1.40 (m, 2H), 1.39-1.28 (m, 1H), 1.06-0.95 (m, 1H),
25 0.91-0.81 (m, 7H), 0.79 (t, J = 7.3 Hz, 3H), 0.75-
0.67 (m, 6H).

Example 15**Synthesis of compound 233****Synthesis of compound 15b:**

- 5 Boc-Alanine (15a) (5 g, 26.42 mmol) was dissolved in anhydrous DMF (63 mL) at 0°C before 3-aminopropionitrile (1.9 mL, 26.42 mmol) and HOBt (3.5 g, 26.42 mmol) were added. To this solution was added DCC (26.4 mL, 26.4 mmol, 1.0 M in dichloromethane) via
- 10 syringe. The mixture was stirred at 0°C for 24 h. The generated DCU was filtered out through a pad of Celite and washed with cold dichloromethane. The filtrate was concentrated *in vacuo* and the residue re-dissolved in EtOAc and washed with 1N HCl
- 15 (aqueous), saturated NaHCO₃, and saturated brine. The organic phase was dried (Na₂SO₄), filtered and concentrated *in vacuo* to give 6.3 g of a pale brownish solid. Purification by flash chromatography using EtOAc/hexane (7/3) gave compound 15b as a white
- 20 solid (3.94 g, 62%). HPLC (95%); MS (FAB) 242.1 (MH⁺), 264.1 (MNa⁺); ¹H-NMR (DMSO-d₆) δ 8.10 (bs, 1H), 6.88 (d, J = 7 Hz, 1H), 3.86 (m, 1H), 3.35-3.2 (m, 2H), 1.37 (s, 9H), 1.18 (d, J = 7.3 Hz, 2H).

25 Synthesis of compound 15c:

To a solution of compound **15b** (3.92 g, 17.5 mmol) in THF (350 mL) at 0°C was added sequentially triphenylphosphine (7.2 g, 35.4 mmol), DEAD (5.5 mL, 35.1 mmol), and trimethylsilylazide (4.66 mL, 35.1 mmol). The reaction was warmed to RT and left to stir 16 h. The mixture was then heated to 70°C for 4 h and stirred an additional 48 h at RT. The solution was cooled to 0°C and treated with excess 5.5% aqueous $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$ [caution, add slowly dropwise]. The crude mixture was extracted with EtOAc (3 x 100 mL) and washed with saturated brine before being dried (Na_2SO_4), filtered and concentrated *in vacuo*. Purification by flash chromatography using EtOAc/hexane (6/4) gave compound **15c** as a white solid (3.3 g, 76%). MS (FAB) 267.1 (MH^+); ^1H -NMR ($\text{DMSO}-d_6$) δ 7.75 (d, $J =$, 1H), 5.1-5.02 (m, 1H), 4.73 (t, $J =$ 2H), 3.18 (t, $J =$ 2H), 1.49 (d, $J =$ X, 3H), 1.36 (s, 9H).

Final deprotection of the tetrazole and the ester functionalities was accomplished by saponification. The protected peptide **15d** (38 mg, 0.033 mmol) was dissolved in THF (0.5 mL), MeOH (0.25 mL) and H_2O (0.25 mL) before being treated with aqueous NaOH (0.1 mL of a 2 N solution, 0.198 mmol) for 4 h. The mixture was concentrated *in vacuo* and the crude product purified by preparative HPLC to give after lyophilization compound **233** as a white solid (7.5 mg, 25%). HPLC (98%); MS (FAB) 913.5 ($\text{M}-\text{H}^-$); HRMS calcd for $\text{C}_{41}\text{H}_{62}\text{N}_{12}\text{O}_{12}$ (MH^+) 915.4688, found: 915.47250. ^1H -NMR ($\text{DMSO}-d_6$) δ 10.32 (bs, 1H), 8.23 (d, $J =$ 7.6 Hz, 1H), 8.05 (d, $J =$ 7.6 Hz, 1H), 7.99 (d, $J =$ 8.6 Hz, 1H), 7.90 (d, $J =$ 9.2 Hz, 1H), 7.35-7.27 (m, 5H), 6.99 (m, 1H), 5.12 (m, 1H), 4.56-4.42 (m, 4H), 4.41-

4.34 (m, 1H), 4.34-4.17 (m, 5H), 3.70 (dd, $J = 10.5$,
10.5 Hz, 1H), 3.15 (bm, 1H), 2.67-2.61 (m, 2H), 2.48-
2.40 (m, 1H), 2.30-2.23 (m, 1H), 2.22-2.15 (m, 2H),
2.02 -1.92 (m, 2H), 1.87-1.81 (m, 1H), 1.80 (s, 3H),
5 1.77-1.67 (m, 1H), 1.67-1.57 (m, 1H), 1.51 (d, $J = 7$
Hz, 3H), 1.45-1.27 (m, 3H), 1.06-0.94 (m, 1H), 0.87
(dd, $J = 6.4$, 6.4 Hz, 6H), 0.82 (t, $J = 7.0$ Hz, 3H),
0.72-0.62 (m, 6H).

10 Example 16

Synthesis of compound 107

To Boc-(L)Nvl-OH (0.28 g, 1.28 mmol) was added
benzylamine (0.163 g, 1.53 mmol), TBTU (0.45 g, 1.41
mmol), and diisopropylethylamine (0.45 mL, 2.56 mmol)
15 in DMF (10 mL) for 16 h. The reaction was
concentrated and the residue dissolved in EtOAc (80
mL) and washed sequentially with saturated aqueous
NaHCO₃, 10% aqueous HCl, and brine before being dried
(MgSO₄), filtered and concentrated *in vacuo* to give a
20 white solid (0.18 g, 46%) which was 91% homogeneous
by analytical HPLC. This material (37 mg, 0.12 mmol)
was treated with 4 N HCl/dioxane (5 mL) for 30 min
before being concentrated *in vacuo*. The hydrochloride
salt (0.12 mmol) was combined with the pentapeptide
25 **10h** (0.10 g, 0.11 mmol), TBTU (39 mg, 0.12 mmol) and
diisopropylethylamine (0.07 mL, 0.38 mmol) in DMF (8
mL) and stirred for 16 h. The reaction mixture was
concentrated and the residue dissolved in EtOAc and
washed sequentially with saturated aqueous NaHCO₃,
30 10% aqueous HCl, and brine before being dried
(MgSO₄), filtered, and concentrated *in vacuo* to give
a white solid (0.12 g, 89%). The peptide was
deprotected with neat TFA (5 mL) for 1 h before being

concentrated. The compound was purified by preparative HPLC to give compound **107** (39 mg, 39%). HPLC (98.5%); FAB MS m/z : 908 (MH^+); HRMS calcd for $C_{46}H_{65}N_7O_{12}$ (MH^+) 908.47693, found: 908.47230; AAA OK;

5 1H -NMR (DMSO- d_6) δ 12.5-11.9 (bs, 2H), 8.30 (t, J = 5.7 Hz, 1H), 8.15 (d, J = 7.3 Hz, 1H), 8.02 (m, 3H), 7.79 (d, J = 6.8 Hz, 1H), 7.37-7.19 (m, 10H), 4.57-4.39 (m, 3H), 4.33-4.14 (m, 6H), 4.11 (d, J = 11.5 Hz, 1H), 3.68 (dd, J = 10.8, 4.1 Hz, 1H), 2.63 (dd, J = 16.2, 6.2 Hz, 1H), 2.45 (dd, J = 16.2, 6.2 Hz, 1H), 2.23-2.15 (m, 3H), 2.02-1.85 (m, 3H), 1.82 (s, 3H), 1.79-1.67 (m, 2H), 1.66-1.48 (m, 2H), 1.40-1.23 (m, 3H), 1.08-0.97 (m, 1H), 0.92-0.81 (m, 11H), 0.73 (t, J = 7.95 Hz, 6H).

10

15

Example 17

Synthesis of compound 108

Compound **108** was prepared according to the procedure for compound **107**.

20 HPLC (99.9%); FAB MS m/z : 922 (MH^+); HRMS calcd for $C_{47}H_{67}N_7O_{12}$ (MH^+) 922.49261, found: 922.49560; 1H -NMR (DMSO- d_6) δ 12.5-11.9 (bs, 2H), 8.21 (d, J = 7.95 Hz, 1H), 8.15 (d, J = 7.6 Hz, 1H), 8.05 (d, J = 7.6 Hz, 2H), 7.91 (d, J = 7.95 Hz, 1H), 7.79 (8.9 Hz, 1H), 7.36-7.25 (m, 10H), 7.23-7.17 (m, 1H), 4.92-4.83 (m, 1H), 4.53 (m, 1H), 4.51 (d, J = 7.95 Hz, 1H), 4.44 (d, J = 7.95 Hz, 1H), 4.42 (m, 1H), 4.33-4.25 (m, 2H), 4.24-4.14 (m, 3H), 4.11 (d, J = 11 Hz, 1H), 3.71 (m, 1H), 2.63 (dd, J = 11.0, 4.0 Hz, 1H), 2.45 (dd, J = 11.0, 4.0 Hz, 1H), 2.23-2.14 (m, 3H), 2.04-1.86 (m, 3H), 1.82 (s, 3H), 1.80-1.66 (m, 2H), 1.62-1.42 (m, 2H), 1.33 (d, J = 7.0 Hz, 3H), 1.30-1.17 (m, 2H), 1.07-0.96 (m, 1H), 0.88 (m, 6H), 0.81 (t, J = 7.3 Hz, 3H), 0.73 (t, J = 7.6 Hz, 6H).

25

30

Example 18**RECOMBINANT HCV NS3 PROTEASE RADIOMETRIC ASSAY**

- 5 a) Cloning, expression and purification of the recombinant HCV NS3 protease type 1b

Serum from an HCV-infected patient was obtained through an external collaboration (Bernard Willems MD, Hôpital St-Luc, Montréal, Canada and Dr. Donald Murphy, Laboratoire de Santé Publique du Québec, Ste-Anne de Bellevue, Canada). An engineered full-length cDNA template of the HCV genome was constructed from DNA fragments obtained by reverse transcription-PCR (RT-PCR) of serum RNA and using specific primers selected on the basis of homology between other genotype 1b strains. From the determination of the entire genomic sequence, a genotype 1b was assigned to the HCV isolate according to the classification of Simmonds et al. (J. Clin. Microbiol., (1993), 31, p.1493-1503). The amino acid sequence of the non-structural region, NS2-NS4B, was shown to be greater than 93% identical to HCV genotype 1b (BK, JK and 483 isolates) and 88% identical to HCV genotype 1a (HCV-1 isolate). A DNA fragment encoding the polyprotein precursor (NS3/NS4A/NS4B/NS5A/NS5B) was generated by PCR and introduced into eucaryotic expression vectors. After transient transfection, the polyprotein processing mediated by the HCV NS3 protease was demonstrated by the presence of the mature NS3 protein using Western blot analysis. The mature NS3 protein was not observed with expression of a polyprotein precursor containing the mutation

S1165A, which inactivates the NS3 protease, confirming the functionality of the HCV NS3 protease.

The DNA fragment encoding the recombinant HCV NS3
5 protease (amino acid 1027 to 1206) was cloned in the
pET11d bacterial expression vector. The NS3 protease
expression in *E. coli* BL21(DE3)pLysS was induced by
incubation with 1 mM IPTG for 3 h at 22°C. A typical
fermentation (18 L) yielded approximately 100 g of
10 wet cell paste. The cells were resuspended in lysis
buffer (3.0 mL/g) consisting of 25 mM sodium
phosphate, pH 7.5, 10% glycerol (v/v), 1 mM EDTA,
0.01% NP-40 and stored at -80°C. Cells were thawed
and homogenized following the addition of 5 mM DTT.
15 Magnesium chloride and DNase were then added to the
homogenate at final concentrations of 20 mM and 20 µg/mL
respectively. After a 25 min incubation at 4°C,
the homogenate was sonicated and centrifuged at 15000
x g for 30 min at 4°C. The pH of the supernatant was
20 then adjusted to 6.5 using a 1M sodium phosphate
solution.

An additional gel filtration chromatography step was
added to the 2 step purification procedure described
25 in WO 95/22985 (incorporated herein by reference).
Briefly, the supernatant from the bacterial extract
was loaded on a SP HiTrap column (Pharmacia)
previously equilibrated at a flow rate of 2 mL/min in
buffer A (50 mM sodium phosphate, pH 6.5, 10%
30 glycerol, 1 mM EDTA, 5 mM DTT, 0.01% NP-40). The
column was then washed with buffer A containing 0.15
M NaCl and the protease eluted by applying 10 column
volumes of a linear 0.15 to 0.3 M NaCl gradient. NS3
protease-containing fractions were pooled and diluted

to a final NaCl concentration of 0.1 M. The enzyme was further purified on a HiTrap Heparin column (Pharmacia) equilibrated in buffer B (25 mM sodium phosphate, pH 7.5, 10% glycerol, 5 mM DTT, 0.01% NP-40). The sample was loaded at a flow rate of 3 mL/min. The column was then washed with buffer B containing 0.15 M NaCl at a flow rate of 1.5 mL/min. Two step washes were performed in the presence of buffer B containing 0.3 or 1M NaCl. The protease was recovered in the 0.3M NaCl wash, diluted 3-fold with buffer B, reapplied on the HiTrap Heparin column and eluted with buffer B containing 0.4 M NaCl. Finally, the NS3 protease-containing fractions were applied on a Superdex 75 HiLoad 16/60 column (Pharmacia) equilibrated in buffer B containing 0.3 M NaCl. The purity of the HCV NS3 protease obtained from the pooled fractions was judged to be greater than 95% by SDS-PAGE followed by densitometry analysis.

The enzyme was stored at -80°C and was thawed on ice and diluted just prior to use.

Example 19

RECOMBINANT HCV NS3 PROTEASE/NS4A COFACTOR PEPTIDE

RADIOMETRIC ASSAY

The enzyme was cloned, expressed and prepared according to the protocol described in Example 18. The enzyme was stored at -80°C, thawed on ice and diluted just prior to use in the assay buffer containing the NS4A cofactor peptide.

The substrate used for the NS3 protease/NS4A cofactor peptide radiometric assay, DDIVPC-SMSYTW, is cleaved

between the cysteine and the serine residues by the enzyme. The sequence DDIVPC-SMSYTW corresponds to the NS5A/NS5B natural cleavage site in which the cysteine residue in P2 has been substituted for a proline. The peptide substrate DDIVPC-SMSYTW and the tracer biotin-DDIVPC-SMS[¹²⁵I-Y]TW are incubated with the recombinant NS3 protease and the NS4A peptide cofactor KKGSVVIVGRIILSGRK (molar ratio enzyme: cofactor 1:100) in the absence or presence of inhibitors. The separation of substrate from products is performed by adding avidin-coated agarose beads to the assay mixture followed by filtration. The amount of SMS[¹²⁵I-Y]TW product found in the filtrate allows for the calculation of the percentage of substrate conversion and of the percentage of inhibition.

A. Reagents

Tris and Tris-HCl (UltraPure) were obtained from Gibco-BRL. Glycerol (UltraPure), MES and BSA were purchased from Sigma. TCEP was obtained from Pierce, DMSO from Aldrich and NaOH from Anachemia.

Assay buffer: 50 mM Tris HCl, pH 7.5, 30% (w/v) glycerol, 1 mg/mL BSA, 1 mM TCEP (TCEP added just prior to use from a 1 M stock solution in water).

Substrate: DDIVPCSMSYTW, 25 μ M final concentration (from a 2 mM stock solution in DMSO stored at -20°C to avoid oxidation).

Tracer: reduced mono iodinated substrate biotin DDIVPC SMS[¹²⁵I Y]TW (~1 nM final concentration).

90

HCV NS3 protease type 1b, 25 nM final concentration (from a stock solution in 50 mM sodium phosphate, pH 7.5, 10% glycerol, 300 mM NaCl, 5 mM DTT, 0.01% NP-40).

5

NS4A Cofactor peptide: KKGSVVIVGRIILSGRK, 2.5 μ M final concentration (from a 2 mM stock solution in DMSO stored at -20°C).

10 B. Protocol

The assay was performed in a 96-well polypropylene plate from Costar. Each well contained:

- 20 μ L substrate/tracer in assay buffer;
- 15 • 10 μ L \pm inhibitor in 20% DMSO/assay buffer;
- 10 μ L NS3 protease 1b/NS4 cofactor peptide (molar ratio 1:100).

Blank (no inhibitor and no enzyme) and control (no
20 inhibitor) were also prepared on the same assay plate.

The enzymatic reaction was initiated by the addition of the enzyme/NS4A peptide solution and the assay
25 mixture was incubated for 40 min at 23°C under gentle agitation. Ten (10) μ L of 0.5N NaOH were added and 10 μ L 1 M MES, pH 5.8 were added to quench the enzymatic reaction.

30 Twenty (20) μ L of avidin-coated agarose beads (purchased from Pierce) were added in a Millipore MADP N65 filtration plate. The quenched assay mixture

was transferred to the filtration plate, and incubated for 60 min at 23°C under gentle agitation.

The plates were filtered using a Millipore
5 MultiScreen Vacuum Manifold Filtration apparatus, and 40 µL of the filtrate was transferred in an opaque 96-well plate containing 60 µL of scintillation fluid per well.

10 The filtrates were counted on a Packard TopCount instrument using a ¹²⁵I-liquid protocol for 1 minute.

The %inhibition was calculated with the following equation:

15

$$100 - [(counts_{inh} - counts_{blank}) / (counts_{ctl} - counts_{blank}) \times 100]$$

A non-linear curve fit with the Hill model was applied to the inhibition-concentration data, and the
20 50% effective concentration (IC₅₀) was calculated by the use of SAS software (Statistical Software System; SAS Institute, Inc., Cary, N.C.).

Example 20

25 SPECIFICITY ASSAYS

The specificity of the compounds was determined against a variety of serine proteases: human
leukocyte elastase, porcine pancreatic elastase and
30 bovine pancreatic α-chymotrypsin and one cysteine protease: human liver cathepsin B. In all cases a 96-well plate format protocol using a colorimetric p-nitroanilide (pNA) substrate specific for each enzyme was used. Each assay included a 1 h enzyme-inhibitor

pre-incubation at 30°C followed by addition of substrate and hydrolysis to $\approx 30\%$ conversion as measured on a UV Thermomax® microplate reader. Substrate concentrations were kept as low as possible compared to K_M to reduce substrate competition. Compound concentrations varied from 300 to 0.06 μM depending on their potency. The final conditions for each assay were as follows:

50mM Tris-HCl pH 8, 0.5 M Na_2SO_4 , 50 mM NaCl, 0.1 mM EDTA, 3% DMSO, 0.01% Tween-20 with;
[100 μM Succ-AAPF-pNA and 250 pM α -chymotrypsin],
[133 μM Succ-AAA-pNA and 8 nM porcine elastase], [133 μM Succ-AAV-pNA and 8 nM leukocyte elastase]; or
[100 mM NaHPO_4 pH 6, 0.1 mM EDTA, 3% DMSO, 1mM TCEP, 0.01% Tween-20, 30 μM Z-FR-pNA and 5 nM cathepsin B (the stock enzyme was activated in buffer containing 20 mM TCEP before use)].

A representative example is summarized below for porcine pancreatic elastase:

In a polystyrene flat-bottom 96-well plate were added using a Biomek liquid handler (Beckman):

- 40 μL of assay buffer (50 mM Tris-HCl pH 8, 50 mM NaCl, 0.1 mM EDTA);
- 20 μL of enzyme solution (50 mM Tris-HCl pH 8, 50 mM NaCl, 0.1 mM EDTA, 0.02% Tween-20, 40 nM porcine pancreatic elastase); and
- 20 μL of inhibitor solution (50 mM Tris-HCl, pH 8, 50 mM NaCl, 0.1 mM EDTA, 0.02% Tween-20, 1.5 mM-0.3 μM inhibitor, 15% v/v DMSO).

After 60 min pre-incubation at 30°C, 20 µL of substrate solution (50 mM Tris-HCl, pH 8, 0.5 M Na₂SO₄, 50 mM NaCl, 0.1 mM EDTA, 665 µM Succ-AAA-pNA) were added to each well and the reaction was further incubated at 30°C for 60 min after which time the absorbance was read on the UV Thermomax® plate reader. Rows of wells were allocated for controls (no inhibitor) and for blanks (no inhibitor and no enzyme).

10

The sequential 2-fold dilutions of the inhibitor solution were performed on a separate plate by the liquid handler using 50 mM Tris-HCl pH 8, 50 mM NaCl, 0.1 mM EDTA, 0.02% Tween-20, 15% DMSO. All other specificity assays were performed in a similar fashion.

15

The percentage of inhibition was calculated using the formula:

20

$$[1 - ((UV_{inh} - UV_{blank}) / (UV_{ctl} - UV_{blank}))] \times 100$$

A non-linear curve fit with the Hill model was applied to the inhibition-concentration data, and the 50% effective concentration (IC₅₀) was calculated by the use of SAS software (Statistical Software System; SAS Institute, Inc., Cary, N.C.).

25

Example 21

Tables of compounds

30

The following tables list IC₅₀ values of compounds representative of the invention.

The following abbreviations are used:

IC₅₀: The concentration required to obtain 50% inhibition in the NS3 protease/NS4A cofactor peptide radiometric assay according to Example 19.

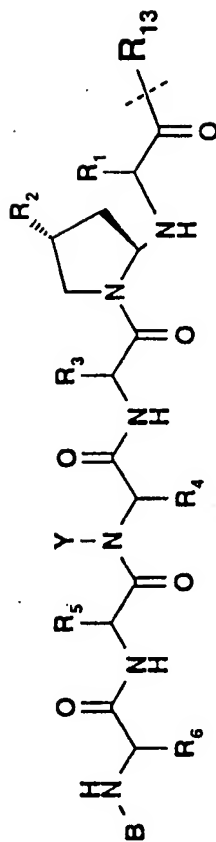
5 **HLE**: The concentration required to obtain 50% inhibition in the human leukocyte elastase assay;

PPE: The concentration required to obtain 50% inhibition in the porcine pancreatic elastase assay;

Other: Figures unmarked indicate the concentration
10 required to obtain 50% inhibition in the bovine pancreatic α -chymotrypsin assay; figures marked with ** indicate the concentration required to obtain 50% inhibition in the human liver cathepsin B assay; **MS**: Mass spectrometric data (MH⁺ from FAB); **AAA**: amino
15 acid analysis data expressed in % peptide recovery; **Acpr**: 1-amino-cyclopropylcarboxylic acid; **Acpe**: 1-amino-cyclopentylcarboxylic acid; **Abu**: aminobutyric acid; **Chg**: cyclohexylglycine (2-amino-2-cyclohexyl-acetic acid); **Hyp**: 4(R)-hydroxyproline; **Hyp(4-Bn)**:
20 4(R)-benzyloxyproline; **Pip**: pipecolic acid; **Tbg**: tert-butylglycine; **Ac**: acetyl; **Bn**: benzyl; **O-Bn**: benzyloxy; **DAD**: 3-carboxypropionyl; and **DAE**: 4-carboxybutyryl.

Table 1

P6 P5 P4 P3 P2 P1



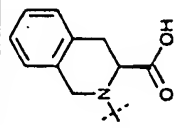
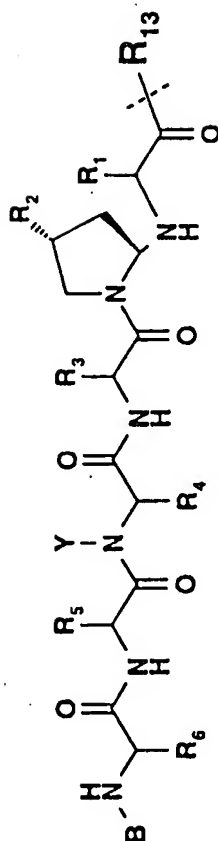
cpd	B	P6	P5	P4	P3	R ₂	R ₁	R ₁₃	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	OTHER (μM)	MS (MH ⁺)	AAA (%)
101	Ac	Asp	D-Glu	Ile	Val	O-Bn	ethyl	CF ₃	9.4	<1.2			857.4	
102	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	CF ₂ CF ₃	0.21				921	99.2
103	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	C(O)NH-Bn	0.023				936	
104	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	H	0.14	7	8	8	803	115
105	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	NH ₂	54				818	108
106	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	CH ₂ CH ₂ -Ph	5.4	16			908	107.8
107	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	NHCH ₂ Ph	3				908	100.8
108	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	(S)-NH-CH(Me)Ph	0.71	3	>300	>300	922	107
109	Ac	---	---	Chg	Val	O-Bn	propyl	C(O)-NH-Bn	23	2			718.3	
110	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl		8				(MH ⁺) 753.5	

Table 1

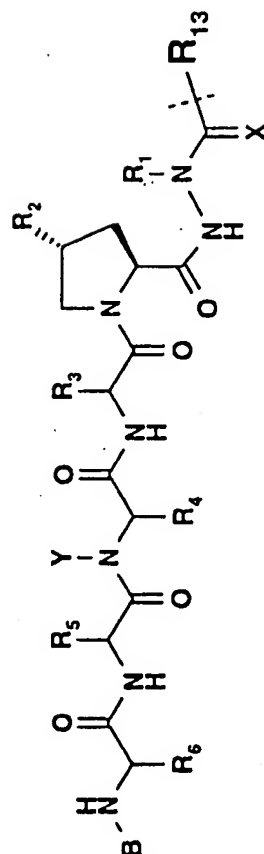
P6 P5 P4 P3 P2 P1



cpd	B	P6	P5	P4	P3	R ₂	R ₁	R ₁₃	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	OTHER (μM)	MS (MH ⁺)	AAA (%)
111	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl		20					
112	Ac	Asp	D-Glu	Ile	Val	H	propyl	C(O)-NH-Bn	2	0.03	<0.06	10.3	814.4	104.4
113	Ac	Asp	D-Glu	Ile	Val	H	propyl	CF ₂ -CF ₃	12.8	0.07	<0.06	18		
114	Ac	Asp	D-Glu	Ile	Val	H	propyl	CF ₃	23.5	0.05	0.2	4.4	749.3	106.7
115	Ac	Asp	D-Glu	Ile	Val	H	propyl	C(O)NH-Bn	0.66	0.11	<0.06	30	814	99.4
116	Ac	---	---	Chg	Val	O-Bn	propyl	C(O)NH-CH ₂ -4-pyridine	25					

Table 2

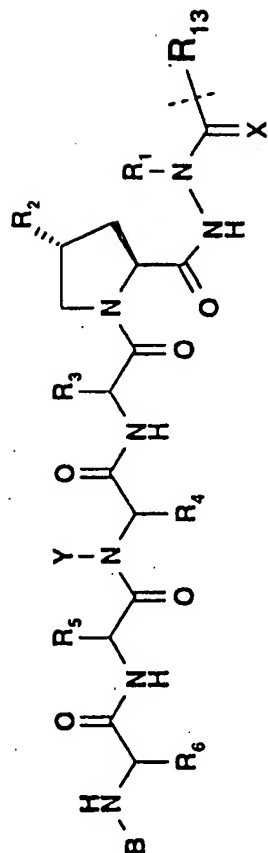
P6 P5 P4 P3 P2 P1



entry #	B	P6	P5	P4	P3	R2	R1	X	R13	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	MS (MH ⁺)	AAA (%)
201	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	NHCH ₂ -C(O)OEt	3.9	27.4	168	905.2	
202	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	CH ₂ CH ₂ -Ph	0.63	5.5		908.4	
203	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	NHCH ₂ -Ph	0.59			909.6	
204	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	(R)-NH-CH(Me)Ph	4.2			923.6	
205	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	(S)-NH-CH(Me)Ph	0.078	5.1	4.1	923.6	93.4
206	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	OCH ₂ Ph	0.79	<0.6	<0.6	910	95.6
207	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	NHCH ₂ -C(O)OH	3.75			877.1	106.5
208	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	CH ₃	14.5			818.2	101.9
209	Ac	Asp	D-Glu	Ile	Val	O-Bn	Propyl	O	NH ₂	20.5			819.3	100.6
210	Ac	Asp	D-Glu	Ile	Val	O-Bn	Butyl	O	(S)-NH-CH(Me)Ph	0.085	4		937.5	95.4
211	Ac	Asp	D-Glu	Ile	Val	O-Bn	Butyl	O	NH ₂	47			833	84

Table 2

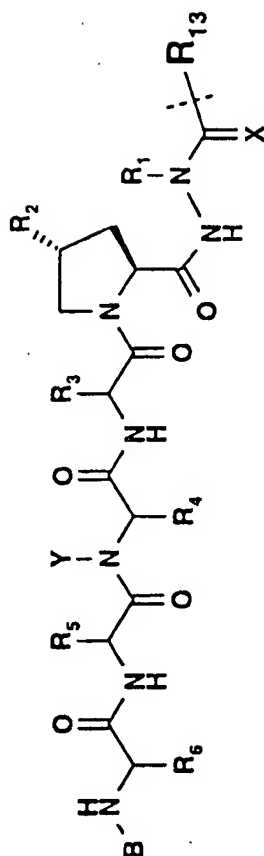
P6 P5 P4 P3 P2 P1



entry #	B	P6	P5	P4	P3	P2	P1	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	MS (MH ⁺)	AAA (%)
212	Ac	Asp	D-Glu	Ile	Val			0.58	0.4		974.3	98.9
213	Ac	Asp	D-Glu	Ile	Val			0.079	36		909.9	103.3
214	Ac	Asp	D-Glu	Ile	Val			0.44			937.5	
215	Ac	---	---	Chg	Val			45	5		705.5	95.8
216	Ac	Asp	D-Glu	Ile	Val			9.6			(MH ⁺) 908.5	
217	Ac	Asp	D-Glu	Ile	Val			1.04			803.4	93.2
218	Ac	Asp	D-Glu	Ile	Val			3.3			951.5	99.5
219	Ac	Asp	D-Glu	Ile	Val			0.43	151		951.5	
220	HOOC (CH ₂) ₂ - C(O)	---	D-Asp	Ile	Val			6.9			(MH ⁺) 744.5	97.5
221	Ac	Asp	D-Glu	Ile	Val			0.52	168		895	94
222	Ac	Asp	D-Glu	Ile	Val			8.9	>300		951.4	98.2
223	Ac	Asp	D-Glu	Ile	Val			11			923.5	105.5
224	Ac	Asp	D-Glu	Ile	Val			5			(MH ⁺)	

Table 2

P6 P5 P4 P3 P2 P1



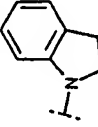
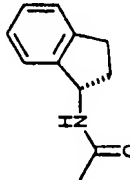
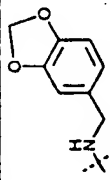
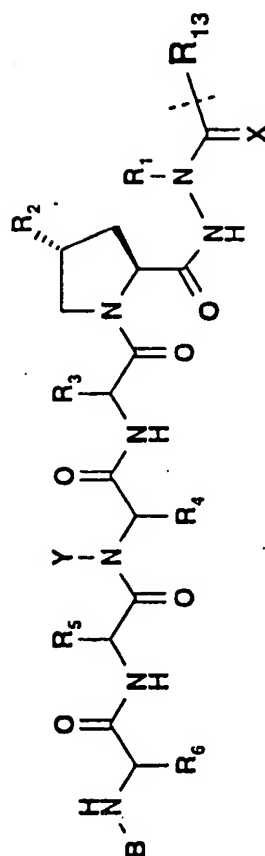
entry #	B	P6	P5	P4	P3	R ₂	R ₁	X	R ₁₃	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	MS (MH ⁺)	AAA (%)
225	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O	COCH ₃	13			923.4	
226	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O		6.3			862.3	102.3
227	Ac	---	---	Chg	Val	O-Bn	propyl	O	COOH	39.5			(MH ⁺) 628.3	
228	Ac	Asp	D-Glu	Ile	Val	O-Bn	CH ₂ CF ₃	O	(S)-NH-CH(Me)Ph	0.63			(MH ⁺) 961.4	
229	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O		0.13	3.1		(MH ⁺) 933.4	94.1
230	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O	(S)-NH-CH(Me)	0.36			929.5	100.6
231	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O		0.5			953.4	107.3

Table 2

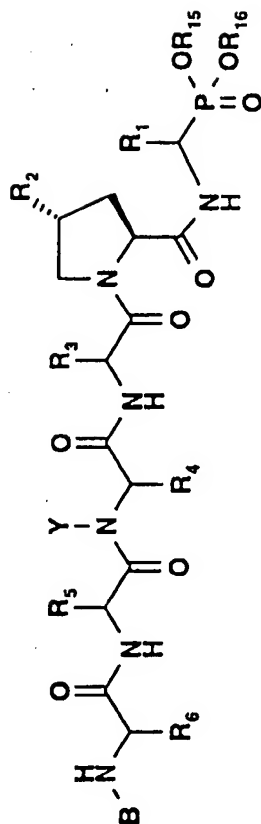
P6 P5 P4 P3 P2 P1



entry #	B	P6	P5	P4	P3	R ₂	R ₁	X	R ₁₃	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	MS (MH ⁺)	AAA (%)
232	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O		3.2			977.4	96.9
233	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	O		1.5			(MH ⁺) 913.5	
234	Ac	Asp	D-Glu	Ile	Val	O-Bn	CH ₂ -CH=CH ₂	O	N-benzyl	3.7			907.5	

Table 3

P6 P5 P4 P3 P2 P1

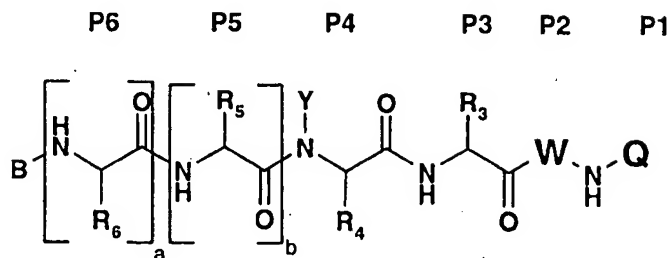


entry #	B	P6	P5	P4	P3	P2	P1	IC ₅₀ (μM)	HLE (μM)	PPE (μM)	OTHER (μM)	MS (MH ⁺)	AAA (%)
301	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	0.029	<0.6	<0.6	3 >300	1007	86.6
302	Ac	Asp	D-Glu	Ile	Val	O-Bn	propyl	26				1007	

What is claimed is:

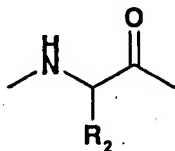
1. A compound of formula I:

5



(I)

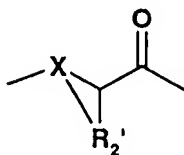
- wherein B is an acyl derivative of formula $\text{R}_{11}\text{-C(O)-}$
 wherein R_{11} is C_{1-10} alkyl optionally substituted with
 10 carboxyl; or R_{11} is C_6 or C_{10} aryl or C_{7-16} aralkyl
 optionally substituted with a C_{1-6} alkyl;
 a is 0 or 1;
 R_6 , when present, is carboxy(lower)alkyl;
 b is 0 or 1;
 15 R_5 , when present, is C_{1-6} alkyl, or
 carboxy(lower)alkyl;
 Y is H or C_{1-6} alkyl;
 R_4 is C_{1-10} alkyl; C_{3-10} cycloalkyl;
 R_3 is C_{1-10} alkyl; C_{3-10} cycloalkyl;
 20 W is a group of formula II:



Formula II

- wherein R_2 is C_{1-10} alkyl or C_{3-7} cycloalkyl optionally
 25 substituted with carboxyl; C_6 or C_{10} aryl; or C_{7-16}
 aralkyl; or

W is a group of formula II':



Formula II'

5

wherein X is CH or N; and

R₂' is C₃₋₄ alkylene that joins X to form a 5- or 6-membered ring, said ring optionally substituted with OH; SH; NH₂; carboxyl; R₁₂; OR₁₂, SR₁₂, NHR₁₂ or NR₁₂R₁₂'

10 wherein R₁₂ and R₁₂' are independently:

cyclic C₃₋₁₆ alkyl or acyclic C₁₋₁₆ alkyl or cyclic C₃₋₁₆ alkenyl or acyclic C₂₋₁₆ alkenyl, said alkyl or alkenyl optionally substituted with NH₂, OH, SH, halo, or carboxyl; said alkyl or alkenyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N; or

15

R₁₂ and R₁₂' are independently C₆ or C₁₀ aryl or C₇₋₁₆ aralkyl optionally substituted with C₁₋₆

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alkyl, NH₂, OH, SH, halo, carboxyl or carboxy(lower)alkyl; said aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;

25

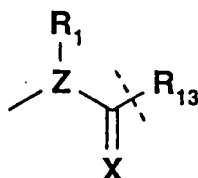
said cyclic alkyl, cyclic alkenyl, aryl or aralkyl being optionally fused with a second 5-, 6-, or 7-membered ring to form a cyclic system or heterocycle, said second ring being

30

optionally substituted with NH₂, OH, SH, halo, carboxyl or carboxy(lower)alkyl; said second ring optionally containing at least one

heteroatom selected independently from the group consisting of: O, S, and N;

Q is a group of the formula:



- 5 wherein Z is CH or N;
 X is O or S;
 R₁ is H, C₁₋₆ alkyl or C₁₋₆ alkenyl both optionally substituted with thio or halo;
 and
 10 when Z is CH, then R₁₃ is H; CF₃; CF₂CF₃; CH₂-R₁₄;
 CH(F)-R₁₄; CF₂-R₁₄; NR₁₄R₁₄' S-R₁₄; or CO-NH-R₁₄ wherein
 R₁₄ and R₁₄' are independently hydrogen, cyclic C₃₋₁₀ alkyl or acyclic C₁₋₁₀ alkyl or cyclic C₃₋₁₀
 15 alkenyl or acyclic C₂₋₁₀ alkenyl, said alkyl or alkenyl optionally substituted with NH₂, OH, SH, halo or carboxyl; said alkyl or alkenyl
 optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N; or
 20 R₁₄ and R₁₄' are independently C₆ or C₁₀ aryl or C₇₋₁₆ aralkyl optionally substituted with C₁₋₆ alkyl, NH₂, OH, SH, halo, carboxyl or carboxy(lower)alkyl or substituted with a
 further C₃₋₇ cycloalkyl, C₆ or C₁₀ aryl, or
 25 heterocycle; said aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;
 said cyclic alkyl, cyclic alkenyl, aryl or
 30 aralkyl being optionally fused with a second 5-, 6-, or 7-membered ring to form a cyclic system

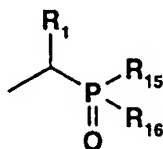
or heterocycle, said second ring being optionally substituted with NH_2 , OH, SH, halo, carboxyl or carboxy(lower)alkyl or substituted with a further C_{3-7} cycloalkyl, C_6 or C_{10} aryl, or heterocycle; said second ring optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;

or R_{14} and R_{14}' are independently C_{1-4} alkyl which when joined together with N form a 3 to 6-membered nitrogen-containing ring which is optionally fused with a further C_{3-7} cycloalkyl, C_6 or C_{10} aryl or heterocycle;

with the proviso that when Z is CH, then R_{13} is not an α -amino acid or an ester thereof;

when Z is N, then R_{13} is H; carboxy; C_{1-6} alkyl optionally substituted with carboxy; $\text{CH}_2\text{-R}_{14}$; $\text{CHR}_{14}\text{R}_{14}'$; CH(F)-R_{14} ; O-R_{14} ; $\text{NR}_{14}\text{R}_{14}'$ or S-R_{14} wherein R_{14} and R_{14}' are as defined above; or

Q is a phosphonate group of the formula:

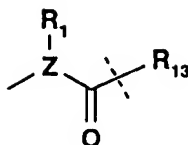


wherein R_{15} and R_{16} are independently C_{6-20} aryloxy; and R_1 is as defined above.

2. A compound of formula I according to claim 1, wherein

Q is a group of the formula:

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wherein **Z** is CH or N;

R₁ is hydrogen, C₁₋₆ alkyl optionally substituted with thiol, or C₁₋₆ alkenyl;

5 and

when **Z** is CH, then **R**₁₃ is H; CF₃; CF₂CF₃; CH₂-**R**₁₄;

CH(F)-**R**₁₄; CF₂-**R**₁₄; NR₁₄**R**₁₄' S-**R**₁₄; CHR₁₄**R**₁₄' or CO-NH-**R**₁₄

wherein

- 10 **R**₁₄ and **R**₁₄' are independently hydrogen, cyclic C₃₋₁₀ alkyl or acyclic C₁₋₁₀ alkyl or cyclic C₃₋₁₀ alkenyl or acyclic C₂₋₁₀ alkenyl, said alkyl or alkenyl optionally substituted with NH₂, OH, SH, halo or carboxyl; said alkyl or alkenyl optionally containing at least one heteroatom
- 15 selected independently from the group consisting of: O, S, and N; or
- R**₁₄ and **R**₁₄' are independently C₆ or C₁₀ aryl or C₇₋₁₆ aralkyl optionally substituted with C₁₋₆ alkyl, NH₂, OH, SH, halo, carboxyl or
- 20 carboxy(lower)alkyl; said aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;
- said cyclic alkyl, cyclic alkenyl, aryl or
- 25 aralkyl being optionally fused with a second 5-, 6-, or 7-membered ring to form a cyclic system or heterocycle, said second ring being optionally substituted with NH₂, OH, SH, halo, carboxyl or carboxy(lower)alkyl; said second
- 30 ring optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N;

with the proviso that, when Z is CH, then R₁₃ is not an α-amino acid or an ester thereof;

when Z is N, then R₁₃ is H; CH₃; NH₂; CH₂-R₁₄; CH(F)-R₁₄; CHR₁₄R₁₄'; O-R₁₄; NH-R₁₄; NR₁₄R₁₄' or S-R₁₄ wherein

5 R₁₄ and R₁₄' are as defined above.

3. The compound of formula I according to claim 2, wherein when X is N then R₂' is substituted with OH; SH; NH₂; carboxyl; R₁₂; OR₁₂, SR₁₂, NHR₁₂ or NR₁₂R₁₂'

10 wherein R₁₂ and R₁₂' are as defined in claim 1.

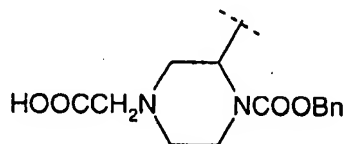
4. The compound of formula I according to claim 1, wherein B is preferably an acyl derivative of formula R₁₁C(O)- wherein R₁₁ is:

15 C₁₋₆ alkyl optionally substituted with carboxyl, C₁₋₆ alkanoyloxy or C₁₋₆ alkoxy;

C₃₋₇ cycloalkyl optionally substituted with carboxyl, MeOC(O), EtOC(O) or BnOC(O);

3-carboxypropionyl (DAD) or 4-carboxybutyryl (DAE);

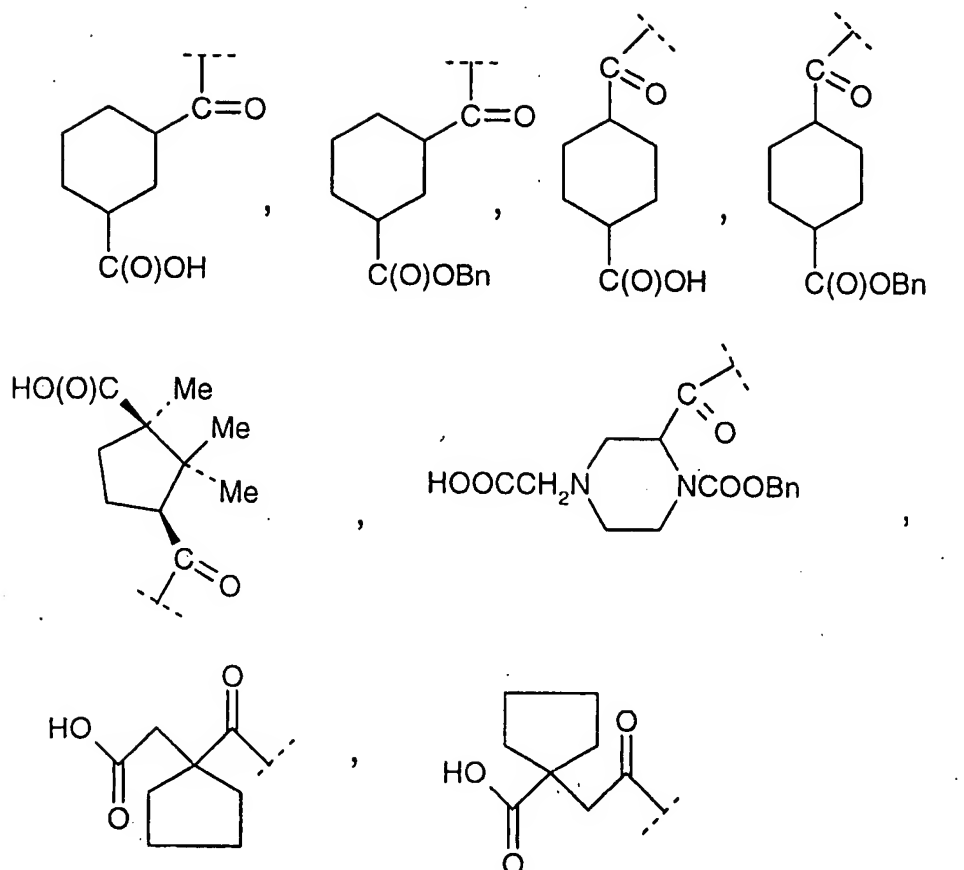
20 or



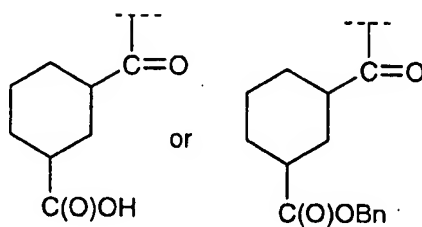
5. The compound of formula I according to claim 4, wherein B is acetyl, 3-carboxypropionyl, 4-

25 carboxylbutyryl, AcOCH₂C(O), Me₃COC(O),

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6. The compound of formula I according to claim 5,
 wherein B is acetyl, 3-carboxypropionyl (DAD), 4-
 5 carboxybutyryl (DAE), $\text{AcOCH}_2\text{C(O)}$,



7. The compound of formula I according to claim 6,
 wherein B is acetyl, or 4-carboxybutyryl (DAE).

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8. The compound of formula I according to claim 7,
 wherein B is acetyl.

9. The compound of formula I according to claim 1 wherein R_6 , when present, is the side chain of Asp or Glu.
- 5 10. The compound of formula I according to claim 9, wherein R_6 , when present, is the side chain of Asp.
11. The compound of formula I according to claim 1, wherein a is 0 and then R_6 is absent.
- 10 12. The compound of formula I according to claim 1, wherein R_5 , when present, is the side chain of an amino acid selected from the group consisting of: D-Asp, L-Asp, D-Glu, L-Glu, D-Val, L-Val, D-tert-butylglycine (Tbg), and L-Tbg.
- 15 13. The compound of formula I according to claim 12, wherein R_5 , when present, is the side chain of D-Asp, D-Val, or D-Glu.
- 20 14. The compound of formula I according to claim 13, wherein R_5 , when present, is the side chain of D-Glu.
- 15 15. The compound of formula I according to claim 1, wherein a is 0 and b is 0, and then both R_6 and R_5 are absent.
- 25 16. The compound of formula I according to claim 1, wherein R_4 is the side chain of an amino acid selected from the group consisting of: Val, cyclohexylglycine (Chg), Tbg, Ile, or Leu.
- 30 17. The compound of formula I according to claim 16, wherein R_4 is the side chain of Chg or Ile.

18. The compound of formula I according to claim 17, wherein R_4 is the side chain of Chg.

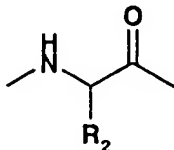
5 19. The compound of formula I according to claim 1, wherein R_3 is the side chain of an amino acid selected from the group consisting of: Ile, Chg, Cha, Val or Glu.

10 20. The compound of formula I according to claim 19, wherein R_3 is the side chain of Val or Chg.

21. The compound of formula I according to claim 20, wherein R_3 is the side chain of Val.

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22. The compound of formula I according to claim 1, wherein W is a group of formula II:

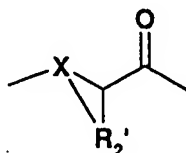


20 wherein R_2 is C_{1-8} alkyl or C_{3-6} cycloalkyl optionally substituted with carboxyl; or benzyl.

23. The compound of formula I according to claim 22, wherein R_2 is the side chain of Asp, aminobutyric acid (Abu) or Val.

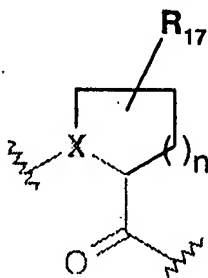
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24. The compound of formula I according to claim 1, wherein W is a group of formula II':



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wherein preferably, **X** is CH or N; and
R₂' is a C₃ or C₄ alkylene that joins **X** to form a 5-
 or 6-membered ring of formula III:



Formula III

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R₂' being optionally substituted at any position with
R₁₇;

wherein **X** is CH or N; **n** is 1 or 2; and

R₁₇ is OH; SH; NH₂; carboxyl; **R₁₂**; **OR₁₂**, **SR₁₂**, **NHR₁₂** or

10 **NR₁₂R₁₂'** wherein **R₁₂** and **R₁₂'** are independently:

cyclic C₃₋₁₆ alkyl or acyclic C₁₋₁₆ alkyl or
 cyclic C₃₋₁₆ alkenyl or acyclic C₂₋₁₆ alkenyl,
 said alkyl or alkenyl optionally substituted
 with NH₂, OH, SH, halo, or carboxyl; said alkyl
 15 or alkenyl optionally containing at least one
 heteroatom independently selected from the group
 consisting of: O, S, and N; or

R₁₂ and **R₁₂'** are independently C₆ or C₁₀ aryl or
 C₇₋₁₆ aralkyl optionally substituted with C₁₋₆

20 alkyl, NH₂, OH, SH, halo, carboxyl or
 carboxy(lower)alkyl; said aryl or aralkyl
 optionally containing at least one heteroatom
 independently selected from the group consisting
 of: O, S, and N;

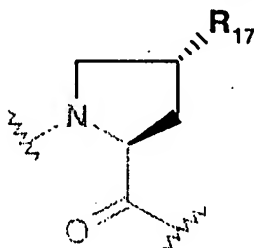
25 said cyclic alkyl, cyclic alkenyl, aryl or
 aralkyl being optionally fused with a second 5-
 , 6-, or 7-membered ring to form a cyclic system
 or heterocycle, said second ring being
 optionally substituted with NH₂, OH, SH, halo,

carboxyl or carboxy(lower)alkyl; said second ring optionally containing at least one heteroatom independently selected from the group consisting of: O, S, and N.

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25. The compound of formula I according to claim 24, wherein X is N; and R_{17} is at the 3-, 4-, or 5-position of the ring.

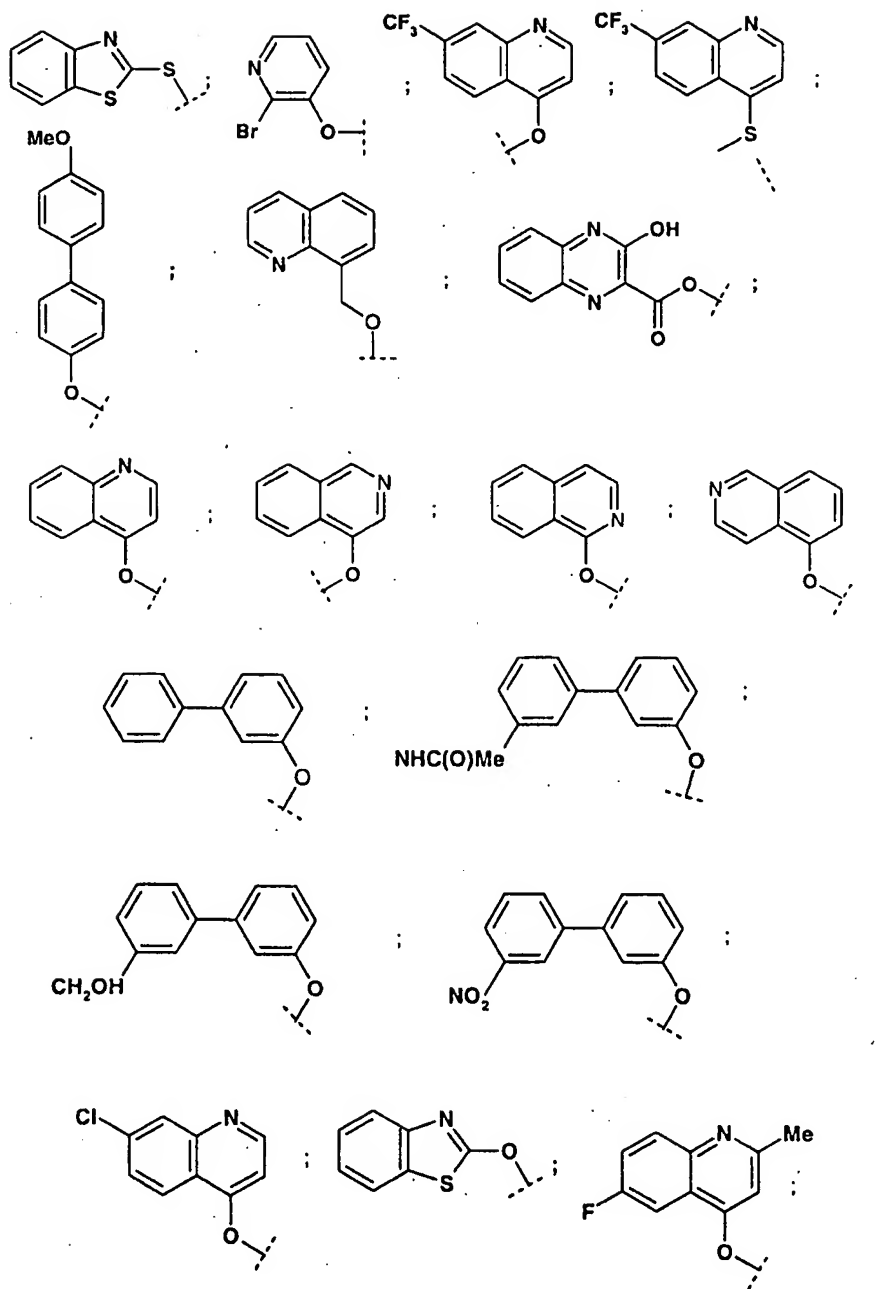
10 26. The compound of formula I according to claim 25, wherein R_2' is the side chain of proline and is substituted with R_{17} at the 4-position with the stereochemistry shown in formula III':



Formula III'

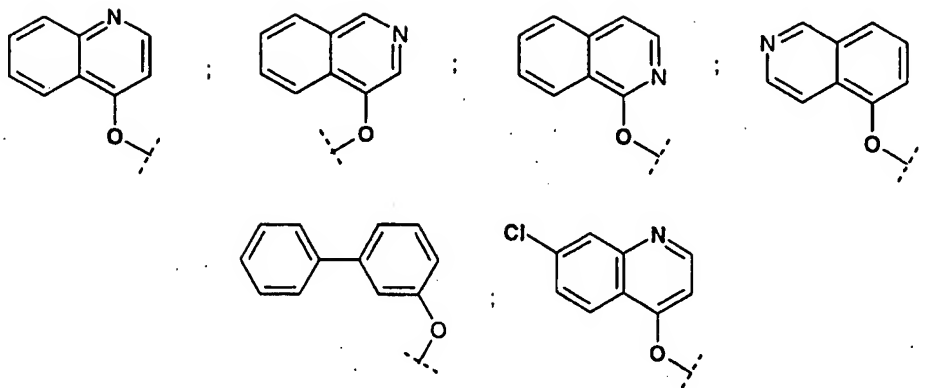
15 wherein R_{17} is OR_{12} wherein R_{12} is a C_6 or C_{10} aryl or C_{7-16} aralkyl, said first aryl or aralkyl optionally substituted with C_{1-6} alkyl, C_{3-7} cycloalkyl, NH_2 , OH , SH , halo, C_{1-6} alkoxy, carboxyl, carboxy(lower)alkyl, or a second aryl or aralkyl; said first and second
20 aryl or aralkyl optionally containing at least one heteroatom selected independently from the group consisting of: O, S, and N.

25 27. The compound of formula I according to claim 26, wherein R_{17} is Bn, $PhCH_2CH_2$, $PhCH_2CH_2CH_2$, O-Bn, o-tolylmethoxy, m-tolylmethoxy, p-tolylmethoxy, 1-naphthalenylmethoxy, 2-naphthalenylmethoxy, (4-tert-butyl)methoxy, (3I-Ph) CH_2O , (4Br-Ph) O , (2Br-Ph) O ,
30 (3Br-Ph) O , (4I-Ph) O , (3Br-Ph) CH_2O , (3,5-Br₂-Ph) CH_2O ,



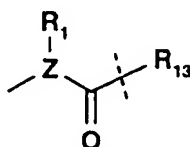
- 5 28. The compound of formula I according to claim 27,
 wherein R₁₇ is O-Bn, 1-naphthalenylmethoxy, 2-
 naphthalenylmethoxy,

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29. The compound of formula I according to claim 27,
 5 wherein R_{17} is O-Bn, 1-naphthalenylmethoxy, or 2-naphthalenylmethoxy.

30. The compound of formula I according to claim 1,
 wherein Q is:

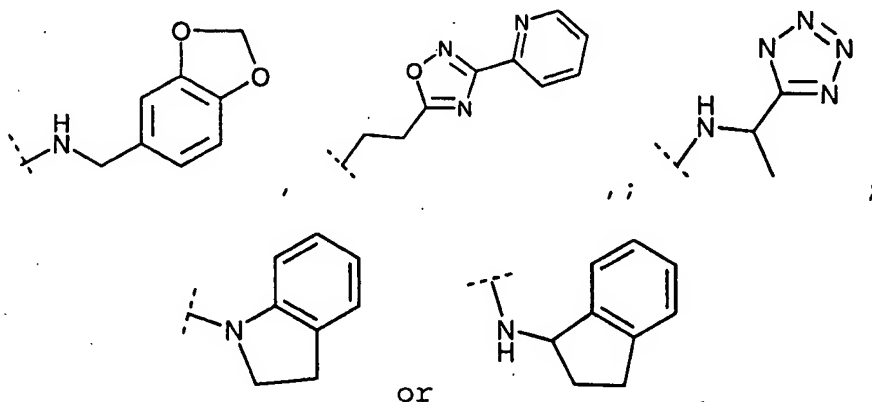


10

wherein Z is preferably CH or N;

when Z is CH: R_{13} is H; CF_3 ; CF_2CF_3 ; CH_2-R_{14} ; $C(O)NH-R_{14}$, $NR_{14}R_{14}$, wherein R_{14} and R_{14} are as defined above
 15 with the proviso that R_{13} is not an α -amino acid or an ester thereof; and

when Z is N: R_{13} is phenyl, or C_{7-16} aralkyl,



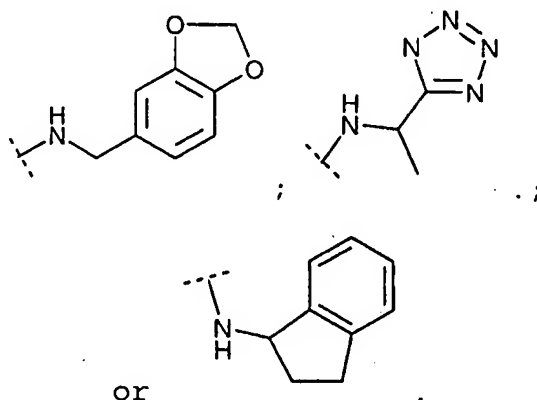
or

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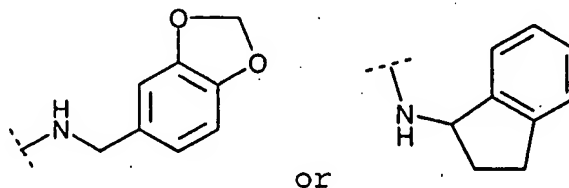
31. The compound of formula I according to claim 30, wherein when Z is CH: R_{13} is H; $NH-R_{14}$ or $C(O)NH-R_{14}$; wherein R_{14} is phenyl or C_{7-16} aralkyl.

5 32. The compound of formula I according to claim 31, wherein R_{13} is H; or $C(O)NH-R_{14}$; and R_{14} is benzyl or $CH(Me)Ph$.

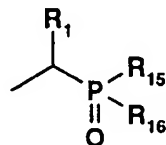
33. The compound of formula I according to claim 30, wherein when Z is N: R_{13} is naphthyl, $NH-CH(Me)Ph$, $NH-CH(Et)Ph$,



15 34. The compound of formula I according to claim 33, wherein R_{13} is, $NH-CH(Me)Ph$, or



35. The compound of formula I according to claim 1, wherein Q is a phosphonate group of the formula:



wherein R_{15} and R_{16} are independently preferably C_6-12 aryloxy.

36. The compound of formula I according to claim 35,
5 wherein R_{15} and R_{16} are each phenoxy.

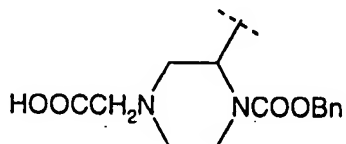
37. The compound of formula I according to claim 1,
wherein R_1 C_{1-6} alkyl or C_{1-6} alkenyl optionally
substituted with halo.

10

38. The compound of formula I according to claim 37,
wherein R_1 is C_{1-5} alkyl or C_{1-4} alkenyl optionally
substituted with fluoro.

15 39. The compound of formula I according to claim 38,
wherein R_1 is ethyl, propyl, isopentyl, or allyl.

40. The compound of formula I according to claim 1,
wherein B is an acyl derivative of formula $R_{11}C(O)-$
20 wherein R_{11} is: C_{1-6} alkyl optionally substituted with
carboxyl, C_{1-6} alkanoyloxy or C_{1-6} alkoxy; C_{3-7}
cycloalkyl optionally substituted with carboxyl,
MeOC(O), EtOC(O) or BnOC(O); 3-carboxypropionyl (DAD)
or 4-carboxybutyryl (DAE); or



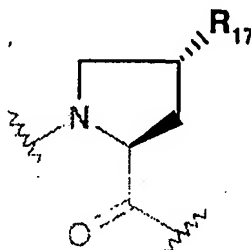
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R_6 , when present, is the side chain of Asp or Glu;
 R_5 , when present, is the side chain of an amino acid
selected from the group consisting of: D-Asp, L-Asp,
D-Glu, L-Glu, D-Val, L-Val, D-tert-butylglycine
30 (Tbg), and L-Tbg;

Y is H or C_{1-3} alkyl;

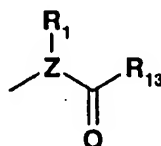
R_4 is the side chain of an amino acid selected from the group consisting of: Val, cyclohexylglycine (Chg), Tbg, Ile, or Leu;

R_3 is the side chain of an amino acid selected from the group consisting of: Ile, Chg, Cha, Val or Glu;
 5 W is:

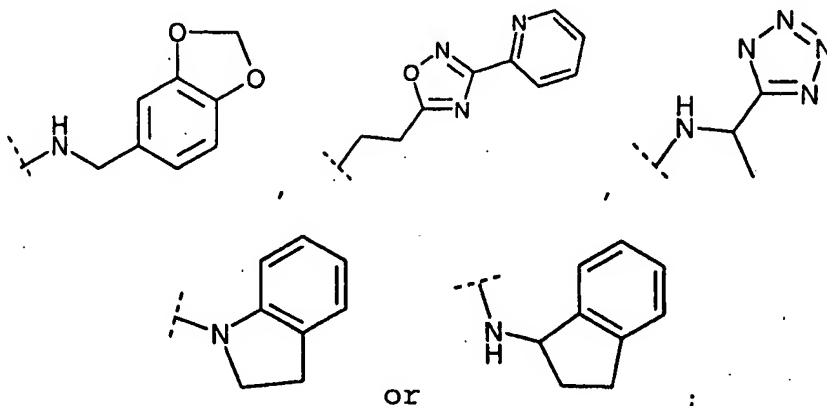


wherein R_{17} is OR_{12} wherein R_{12} is a C_6 or C_{10} aryl or C_{7-16} aralkyl, said first aryl or aralkyl optionally
 10 substituted with C_{1-6} alkyl, C_{3-7} cycloalkyl, NH_2 , OH, SH, halo, C_{1-6} alkoxy, carboxyl, carboxy(lower)alkyl, or a second aryl or aralkyl; said first and second aryl or aralkyl optionally containing at least one heteroatom selected independently from the group
 15 consisting of: O, S, and N;

Q is:

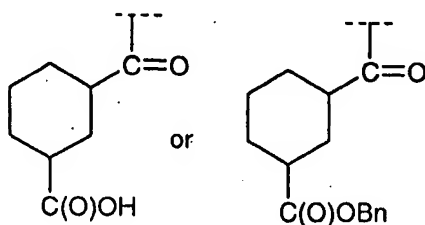


wherein Z is N; and R_{13} is phenyl, C_{7-16} aralkyl,



and R_1 is C_{1-6} alkyl or C_{1-6} alkenyl optionally substituted with halo.

41. The compound of formula I according to claim 40,
5 wherein B is acetyl, 3-carboxypropionyl (DAD), 4-carboxybutyryl (DAE), $AcOCH_2C(O)$,



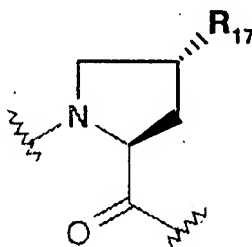
R_6 , when present, is the side chain of Asp, or R_6 is absent;

- 10 R_5 , when present, is the side chain of D-Glu;
or R_5 is absent;

R_4 is the side chain of Chg;

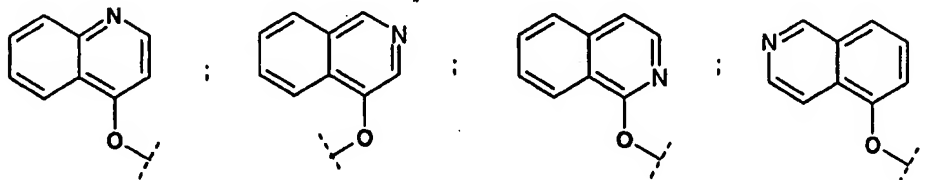
R_3 is the side chain of Val;

W is

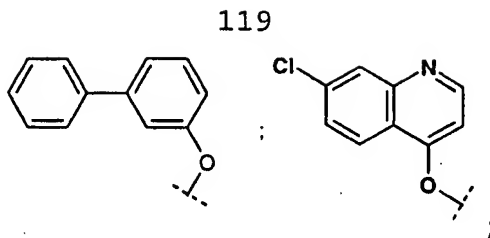


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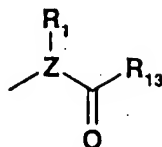
wherein R_{17} is Bn; $PhCH_2CH_2$; $PhCH_2CH_2CH_2$; O-Bn; 1-naphtyloxy; 2-naphtyloxy; 1-naphthalenylmethoxy; 2-naphthalenylmethoxy;



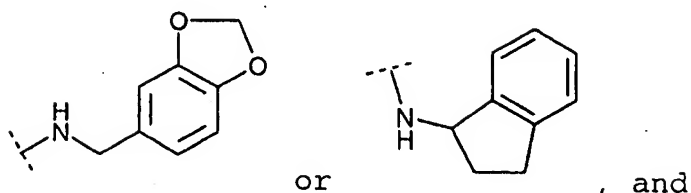
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Q is:



wherein R_{13} is, NH-CH(Me)Ph , or



R_1 is ethyl, propyl, isopentyl, or allyl.

42. The use of a compound according to claim 1 for the treatment of a hepatitis C infection in a mammal comprising administering thereto an anti-hepatitis C virally effective amount of the compound of formula I according to claim 1.

43. A pharmaceutical composition comprising an anti-hepatitis C virally effective amount of a compound of formula I according to claim 1, or a therapeutically acceptable salt or ester thereof, in admixture with a pharmaceutically acceptable carrier medium or auxiliary agent.

44. A method of treating a hepatitis C viral infection in a mammal by administering to the mammal an anti-hepatitis C virally effective amount of the compound of formula I according to claim 1, or a therapeutically acceptable salt or ester thereof.

45. A method of inhibiting the replication of hepatitis C virus by exposing the virus to a hepatitis C viral NS3 protease inhibiting amount of the compound of formula I according to claim 1, or a
5 therapeutically acceptable salt or ester thereof.

46. A method of treating a hepatitis C viral infection in a mammal by administering thereto an anti-hepatitis C virally effective amount of a
10 combination of the compound of formula I according to claim 1, or a therapeutically acceptable salt or ester thereof.

47. A pharmaceutical composition according to claim
15 43, comprising an additional immunomodulatory agent selected from the group consisting of: α -, β -, and δ -interferon.

48. A pharmaceutical composition according to claim
20 43, comprising an additional antiviral agent selected from the group consisting of: ribavirin and amantadine.

49. A pharmaceutical composition according to claim
25 43, additionally comprising other inhibitors of HCV protease.